

Meteorology and Air Quality Patterns in
St. Louis RAPS Program: Upper Level Analyses

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METEOROLOGY AND AIR QUALITY PATTERNS IN
ST. LOUIS RAPS PROGRAM
Upper Level Analyses

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16. ABSTRACT A statistical map-typing procedure was used to stratify regional weather patterns over a 800-km radius area centered on St. Louis. It was intended for application to air pollution studies. Seasonal weather types were obtained for 850-mb height patterns and for geostrophic wind patterns based on surface pressure gradients for the four-year period 1973 through 1976. A total of 21 separate weather map types were identified for the 850-mb level synoptic flow, and a total of 36 map types were identified for the geostrophic wind flow. To show the relationships between the synoptic weather types and air quality, statistical correlations were calculated between the daily map types and observed air quality data using O₃, CO, total suspended particles, sulfate, and nitrate concentrations from the 1975-1976 St. Louis RAPS program. The results show that synoptic map types have a definite and useful correlation with significantly different levels of air pollutant concentrations. The results also indicate that the correlations between map types and average air quality concentrations is better for the 850-mb weather pattern types than for the surface or geostrophic types. This is attributed to the fact that the 850-mb typing scheme stratified the data into fewer types than did the othe two schemes.					
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ABSTRACT

A statistical map typing procedure developed by Lund to classify synoptic weather patterns into similar groups was used to stratify regional weather patterns. The investigation extended over a 800-km radius centered about the greater St. Louis area and was intended for subsequent application to air pollution studies. This typing analysis was applied to 850 mb height data and to geostrophic wind patterns based on surface pressure gradients. In the analysis program, data for a specified number of weather stations on a given day are correlated with the same parameters measured on each of the other days in the four year period 1973 through 1976.

A total of 21 separate weather map types were identified for the 850 mb level synoptic patterns, and a total of 36 map types were identified to classify the geostrophic wind flow across the St. Louis region based on surface pressure differences.

To show the relationships between the synoptic weather types and air quality, this report also contains a statistical comparison of the map types with air quality data. The air quality analysis included ozone, carbon monoxide, total suspended particles, sulfate, and nitrate concentrations sampled in the St. Louis Regional Air Monitoring System of the EPA, for a period of approximately two years during 1975-76.

The results show that the synoptic map typing program, which separates synoptic weather patterns into identifiable map type classes, has a definite and useful correspondence with significantly different levels of air pollutant concentrations. The results also indicate that the correspondence between map types and average air quality concentrations is higher for the 850 mb typing procedure than for the surface or geostrophic typing programs. This is attributed to the fact that the 850 mb typing scheme stratified the data into fewer types than did the other two schemes.

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SECTION 1

INTRODUCTION

The relationship between air pollutant concentrations and the prevailing synoptic weather patterns has been of concern to air quality analysts for some time. The dispersion and transport of pollutants between a source and a receptor is controlled primarily by the wind field at the time the pollutant is emitted into the atmosphere and while it remains airborne. The total wind field includes the direction, speed, and the turbulence or mixing processes of the flow. For transport to occur on a mesoscale basis, with a distance on the order of 100 km and a time factor of one day, the upper level winds (up to a height of 1-2 km) as well as the surface flow are of primary concern. Recently, the influences of the upper level winds and their relation to air pollution have been taken into consideration in the formulation of pollutant dispersion models.

Study Objective

The primary goal of this study was to determine the synoptic weather patterns on a regional scale around St. Louis in terms of a limited number of characteristic types and to relate these patterns to specific pollutant concentrations. To achieve this, the surface weather map types determined using the method of Lund (1963) and developed by Robinson and Boyle (1980) as well as the upper level map types resulting from this study have been used to describe the synoptic weather patterns around St. Louis. Once the synoptic pattern types were determined, they were then correlated with ozone (O_3), carbon monoxide (CO), total suspended particles (TSP), sulfate (SO_4), and nitrate (NO_3) concentrations to obtain relationships between weather types and air quality. The Duncan new multiple range test (Steel and Torrie, 1960) was used to test for statistical significance. Forecasting techniques were not an objective of this study although the delineation of useful weather types and corresponding pollutant relationships could provide a first step toward an objective forecasting procedure.

The historical background and relevance of the Lund (1963, 1971) map typing methodology are fully described in an earlier report by Robinson and Boyle (1980). In their study, the method developed by Lund (1963) was used to develop a series of weather types based upon surface sea level pressures observed at 21 National Weather Service stations over a region of 500 miles radius centered on St. Louis, Missouri. Synoptic data for a four year period, 1973-1976, were obtained for each station. The synoptic data were grouped into seasons in the conventional manner as follows: Winter: December, January, February; Spring: March, April, May; Summer: June, July, August; Fall: September, October, November. The result of the study by Robinson and Boyle

(1980) was the identification of a total of 52 surface map types: 12 winter map types, 13 spring map types, 14 fall map types, and 13 summer map types. For each season, approximately 90 percent of the data was assigned to specific types, which was comparable to 89 percent typed by Lund (1963). After the seasonal map types were defined, they were related to pollutant data obtained from the St. Louis Regional Air Measurement network. Robinson and Boyle (1980), correlated total suspended particles and carbon monoxide with map type. Their results are discussed and compared with the results of this study in a following section.

In this study the emphasis has been placed on large scale weather patterns, i.e. those that could be assessed from regular synoptic maps. This was done so that research results could be applied readily by other investigators to tasks such as model verification.

The present report considers weather types based on 850 mb height observations as an approximation to the wind field and weather patterns at the top of the planetary boundary layer. Although the 850 mb wind field is generally considered to be geostrophic, the synoptic weather types based on 850 mb contours will relate to more than just the wind field. This report also assessed the application of weather map types that approximated the geostrophic wind field directly from an assessment of the sea level pressure gradient field across the study area. As will be shown the geostrophic wind field typing was less successful than the 850 mb contour typing, and thus it might be concluded that the added synoptic pattern inferences in the contours were useful additions to the system. In terms of general pollutant transport within the planetary boundary layer Hoecker (1977) has shown that wind trajectories intermediate between the surface and geostrophic winds are probably the more realistic approximation of the pollutant transport field across the Midwest.

SECTION 2

RESEARCH TECHNIQUES AND RESULTS

This research program was developed in two major phases: first, the development of 2 sets of seasonal weather types, one based on 850 mb contours and the other on surface pressure gradients; and second, the assessment of statistical relationships between air quality in St. Louis and synoptic weather as represented by the predetermined weather types. The synoptic weather types were defined using observations across a major part of the Midwest where the region of interest was defined by a circle of 800 km radius centered on St. Louis. Thus this research provides an extension to upper boundary layer weather patterns of the previous study of relationships between surface weather types and St. Louis air quality by Robinson and Boyle (1980).

The use of 850 mb height data, as mentioned above, to define the synoptic situations, including the general flow regime was a practical choice because of the general availability of this observation and the fact that it would define conditions at about 1.5 km above sea level. Although mid summer maximum mixing depths might exceed this altitude the 850 mb patterns were considered to be a satisfactory representation of the wind and general weather patterns in the upper part of the planetary boundary layer.

The other set of weather map types were developed based on sea level pressure gradients between 17 pairs of National Weather Service stations in the midwest region around St. Louis. These pressure gradient data provide a set of patterns related to the sea level pressure pattern geostrophic wind. As indicated above, this is usually a reasonable approximation of the upper boundary layer (approximately 1 km) wind flow (Slade, 1968). The surface pressure patterns across this region had been determined by Robinson and Boyle (1980) in their study of synoptic weather patterns around St. Louis. Thus the weather situations affecting the St. Louis region could be identified on the basis of three different types of patterns -- the 850 mb height contours, the surface geostrophic winds, and the surface pressures.

850 mb Map Typing

Lund's (1963) technique for map typing pressure patterns was used on the 850 mb geopotential heights instead of the surface sea level pressures to determine the upper level wind flow patterns. Most of the stations used were the same ones used by Robinson and Boyle (1980), with nearby substitute stations for the ones that did not collect upper level radiosonde data. Eighteen stations were used for the map typing procedure, covering an area of approximately 800 km radius centered on St. Louis, Missouri. Table 1 identifies the stations used in this study and also indicates stations

substituted for the original stations used by Robinson and Boyle (1980).

The data used in this analysis were the heights above sea level of the 850 mb surface given in geopotential meters for 00Z (6 pm CST) covering a four year period, 1973-1976. Both the time and the period were chosen for ease of comparison with Robinson and Boyle's (1980) surface map types for the same time and period. The data were separated into four seasons: Winter: December, January, February; Spring: March, April, May; Summer: June, July, August; Fall: September, October, November.

The technique developed by Lund (1963) is basically a simple linear correlation between values at a given set of stations on one day and values at the same stations on a second day. It is then assumed that a good correlation between these values for the two days indicates similar weather patterns, i.e., the same weather map type, on the two selected days.

Table 1. Stations used in this study for 850 mb heights

Call Letters	Name of Station
AHN (ATL)	Athens (Atlanta), Georgia
JAN (MEI)	Jackson (Meridian), Mississippi
BNA	Nashville, Tennessee
LIT (MEM)	Little Rock (Memphis), Arkansas
HTS	Huntington, West Virginia
SAL (STL)	Salem (St. Louis), Illinois
TOP (MKC)	Topeka (Kansas City), Kansas
MON (SGF)	Monet (Springfield), Missouri
DDC	Dodge City, Kansas
PIA (ORD)	Peoria (Chicago), Illinois
FNT (DET)	Flint (Detroit), Michigan
SSM (TVC)	Sault Sainte Marie (Traverse City), Michigan
OMA (DSM)	Omaha (Des Moines), Nebraska
PIA (ALO)	Peoria (Waterloo), Illinois
DAY (IND)	Dayton (Indianapolis), Ohio
HON (FSD)	Huron (Sioux Falls), South Dakota
STC (MSP)	St. Cloud (Minneapolis), Minnesota
OMA (GRI)	Omaha (Grand Island), Nebraska
OKC	Oklahoma City, Oklahoma
SHV*	Shreveport, Louisiana
LGV (SHV)**	Longview (Shreveport), Texas

() Indicates stations used by Robinson and Boyle (1980)

* Shreveport was used from January, 1973 to July, 1975.

** Longview was used from July, 1975 to December, 1976.

A map type is a group of weather maps with a pressure or other weather pattern distinctive enough to be classified separately from other groups of weather maps. The simple linear correlation procedure of Lund (1963) used sea level pressures and was based on the statistical interdependence between the sea level pressures at a given set of stations on one day and the pressures at the same stations on a second day. For example, in the St. Louis program as illustrated by Figure 1 if the X-axis (abscissa) is used to plot station pressures for day 1 and the Y-axis (ordinate) the pressures for day 2, the pressure data from 21 stations will define a corresponding set of 21 points in the X-Y field. Standard statistical techniques can then be used to determine the correlation between station pressures on day 1 versus those on day 2. It is assumed, then, that a "good" correlation between station pressures on the two days is indicative of similar synoptic map patterns on the two days. In Figure 2, the correlation coefficient is 0.81 between June 1, 1973 and June 7, 1973 data. Sea level pressures were used by Robinson and Boyle (1980) while the present study correlates 850 mb heights or sea level pressure gradients over a fixed grid of station pairs.

Previous statistical typing by Lund (1963) and by Robinson and Boyle (1980) were based on weather types being identified by correlations of 0.70 or greater between each map date within the type and an identified base map. The choice of magnitude of the lowest acceptable correlation for determining a type classification was examined in detail by Lund (1963). He determined that the same key or base maps would be identified with the use of either 0.90 or 0.80 instead of 0.70. The major impact of the choice of a value for the lowest acceptable correlation was in number of cases falling into each type and the number of untyped maps. The higher the limiting correlation the fewer the number of maps in each case, but not much difference in the identified types, and the larger the number of untyped maps. After a careful consideration of the limiting correlation value Lund (1963) chose 0.70 as his lowest acceptable correlation. With this correlation limit he was able to type 89% of his map file. Robinson and Boyle (1980) also used 0.70 as a lowest acceptable correlation and typed 90% of their map file. In the present study a value of 0.70 was used for the lowest acceptable correlation coefficient for type identification with the 850 mb height patterns but a value of 0.65 was used with the pressure gradients or geostrophic wind patterns.

Following Lund's guidelines, the St. Louis regional synoptice map types were determined by the following steps:

1. Correlate the 0000 GMT weather parameter value for each day of the selected season with the corresponding parameter value on every day of the season over the four-year test period.
2. Identify the day which has the most other days related to it by a correlation coefficient of 0.70 or greater. Designate this day as the base map for Type A and the maps correlated with it ($r \geq 0.70$) as belonging to the Type A classification.

3. Remove all Type A maps from the map file and then identify the date in the remaining maps which now has the most maps suitably correlated ($r \geq 0.70$) with it. This is the base map for Type B and the maps correlated with it make up the Type B classification.
4. Remove all Type A and Type B maps from the file and proceed to identify the Type C base map and the maps in the Type C classification, as was done for B.
5. Repeat the typing process until most (about 90% or more) of the maps have been typed.
6. Since a given map may be well correlated with more than one type, review all calculated correlations relating each map and the several base maps. Determine that the map type assigned by the first correlation check was the type that had the highest correlation. If the given map is not assigned to the base map type having the highest correlation, move the test map to the map type which is most highly correlated.
7. Continue the map typing process until each of the four seasons has been completed.

In this study, the WSU AMDAHL 470V/6-II computer system was used for the correlation analysis.

This technique identified the following 850 mb level types: 3 winter map types, A(850W) through C(850W); 6 spring map types, A(850SP) through F(850SP); 6 summer map types, A(850S) through F(850S); and 6 fall map types, A(850F) through F(850F). Thus a total of 21 850 mb map types were identified, compared to 52 surface types identified by Robinson and Boyle (1980). The results of the 850 mb map typing procedure are shown in Table 2, with the date of the base map (the map that had the most days correlated with it) and the number of cases or days that correlated with the base map. A correlation coefficient of 0.70 or greater was used to define an acceptable correlation between daily conditions. The map typing technique on 850 mb data was very successful with between 88 and 93 percent of the total number of days being assigned types. The 850 mb base map types are reproduced in Appendix B. Appendix A lists the map type assigned to each day of the 4-year typing period.

Geostrophic Wind Map Typing

The geostrophic wind is defined as a flow that results from the balance between the pressure gradient force and the coriolis force (e.g. a basic meteorological text such as: Hess, 1959). The geostrophic wind is essentially the same as the gradient wind, except that the geostrophic wind neglects the curvature of the flow while the gradient wind includes curvature of the flow. For this research we are neglecting the effects of curvature and are assuming that the geostrophic wind is representative of the flow above the planetary boundary layer.

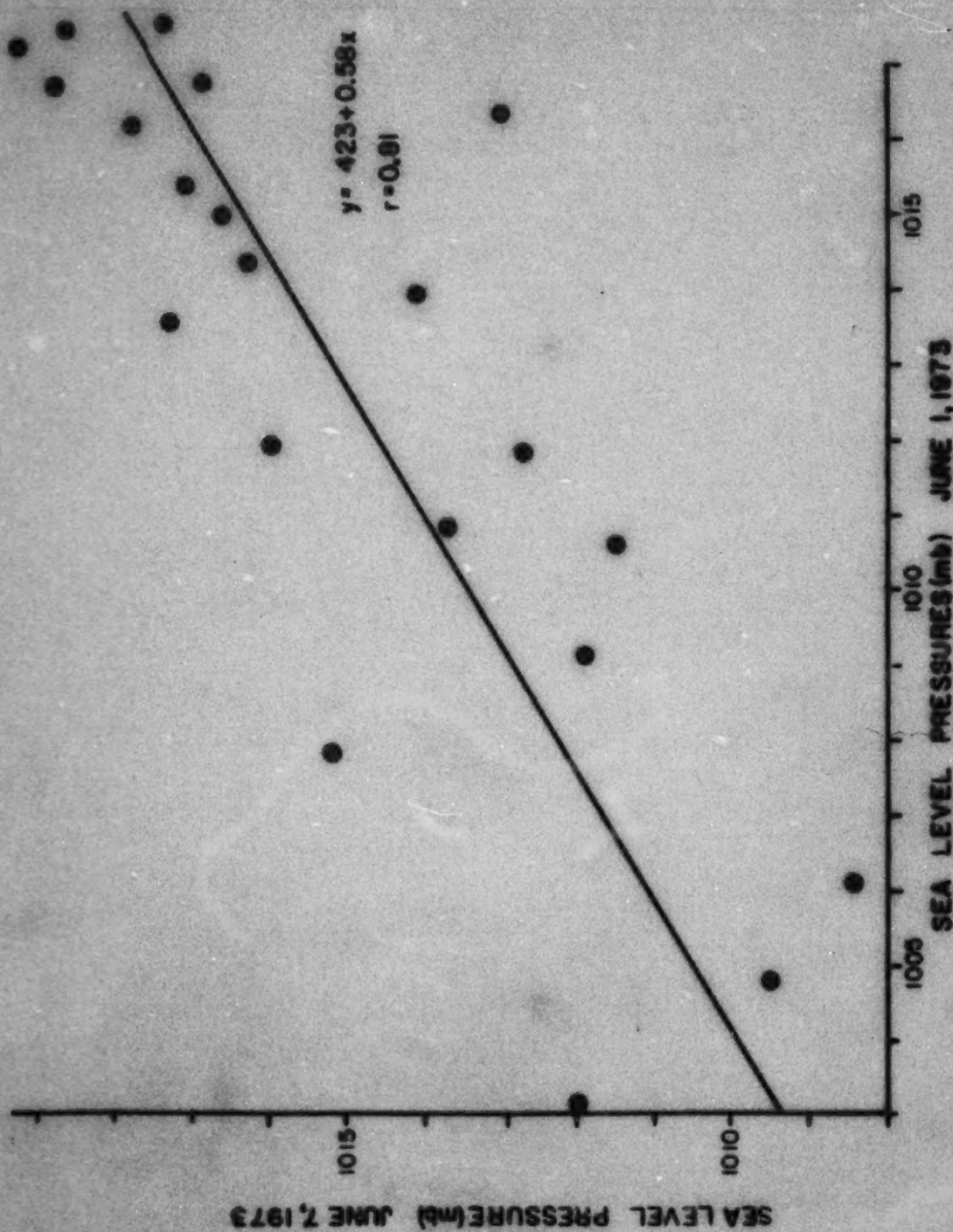


Table 2. Summary of seasonal synoptic map types for 850 mb level, 1973-1976.

Type	Winter (850W)		Spring (850SP)		Summer (850S)		Fall (850F)	
	Date of Base Map	No. of Cases $r \geq 0.70$	Date of Base Map	No. of Cases $r \geq 0.70$	Date of Base Map	No. of Cases $r \geq 0.70$	Date of Base Map	No. of Cases $r \geq 0.70$
A	Feb 13, 1974	199	March 6, 1975	105	June 4, 1975	125	Nov 13, 1973	81
B	Jan 8, 1976	80	May 1, 1973	89	July 30, 1974	65	Sept 30, 1974	70
C	Feb 1, 1973	41	April 11, 1973	82	July 8, 1974	69	Sept 13, 1976	52
D			March 13, 1974	15	June 27, 1974	14	Nov 28, 1973	10
E			April 28, 1976	10	June 6, 1976	14	Sept 26, 1975	12
F			April 25, 1976	11	June 19, 1976	24	Oct 21, 1974	9
Misc		25		36		42		23
Total Typed		320		312		311		234
Total Cases		345		348		353		257
Percent Typed		92.8%		89.7%		88.1%		91.0%

In calculating the geostrophic wind, the pressure gradient, or change in pressure with distance, is the main parameter of concern. The equations used to calculate the geostrophic flow are in the form of:

$$V_g = \frac{1}{\rho f} (dP/dn)$$

where ρ is the density of the air, f is the coriolis parameter which is equal to $2\Omega \sin\phi$ where Ω is the angular velocity of the earth and ϕ is the latitude, and dP/dn is the local change in pressure with distance.

For the purposes of this study, several assumptions were made to simplify the geostrophic wind calculations. First, it was assumed that at any given time the density of the air was the same at all of the stations considered. Second, it was assumed that the coriolis parameter, f , did not vary significantly over the region. With these two assumptions, the geostrophic wind is then proportional to the gradient of sea level pressure over an area, and approximates the actual wind even though the geostrophic wind represents isobars without curvature.

For the purposes of applying the map typing process a data set based on sea level pressure gradients between two selected stations instead of the surface pressure gradient at a given station was used. Since the pairs of weather stations were always the same and since the distance between two stations remains constant, the component of the geostrophic wind normal to the line between the two stations and directed such that low pressure is to the left of the flow.

In this phase of the study, the potential station pairs (i.e., pressure gradients) were selected from the stations used in the other portions of this program, the 850 mb height analysis and the surface analysis of Robinson and Boyle (1980). The goal of the sector selection was to provide variously oriented sectors around St. Louis so that the geostrophic wind components identified by the individual pressure gradients would provide a reasonable representation of the geostrophic flow regime across the region. In designing the sector combinations it was assumed that especially long sectors should be avoided because of the increasing probability of a nonuniform pressure gradient along the sector. It was practical to limit the sector lengths to less than 250 km. In addition the sectors should wherever possible meet with a large angle between adjacent sectors so that the resultant components of the geostrophic wind in the adjacent sectors would define more closely the geostrophic wind vector of that particular region. With these several assumptions, a number of different sector combinations were tested with the final judgement being based on the performance of the particular sector combination in the weather typing procedure described above. The preliminary tests were based on a single season of data to limit computer costs. This procedure resulted in a data set consisting of pressure gradients across 17 sectors using the 17 pairs of stations listed in Table 3. It was necessary, however, to lower the correlation coefficient used to identify a given weather type from ≥ 0.70 to ≥ 0.65 for the geostrophic wind pattern study. This change resulted in the assignment of map types to between 72 and 80% of the days in the 4-year test period.

After the final combination of station pairs were decided upon, the pressure differences were calculated for the four year period for each pair of stations, and the pressure differences were used to map-type the data. When the map typing procedure was carried out on these surface pressure difference data, the results were: 9 map types for winter, A(GeoW) through I(GeoW); 9 spring map types, A(GeoSP) through I(GeoSP); 9 summer map types, A(GeoS) through I(GeoS); and 9 fall map types, A(GeoF) through I(GeoF).

Table 3. Station Pairs Used for Geostrophic Map Types.

Call Letters	Station Combinations
BNA-MEM	Nashville, TN - Memphis, TN
DSM-MKC	Des Moines, IA - Kansas City, MO
DSM-ALO	Des Moines, IA - Waterloo, IA
IND-STL	Indianapolis, IN - St. Louis, MO
IND-HTS	Indianapolis, IN - Huntington, WV
IND-BNA	Indianapolis, IN - Nashville, TN
JAN-SHV	Jackson, MS - Shreveport, LA
MEM-JAN	Memphis, TN - Jackson, MS
MKC-SGF	Kansas City, MO - Springfield, MO
MKC-STL	Kansas City, MO - St. Louis, MO
MSP-ALO	Minneapolis, MN - Waterloo, IA
MSP-FSD	Minneapolis, MN - Sioux Falls, SD
ORD-STL	Chicago, IL - St. Louis, MO
ORD-IND	Chicago, IL - Indianapolis, IN
ORD-ALO	Chicago, IL - Waterloo, IA
SGF-MEM	Springfield, MO - Memphis, TN
TVC-DET	Traverse City, MI - Detroit, MI

*All stations are hourly reporting National Weather Service Stations.

Table 4 gives a summary of the map typing results, with the date of the base map (the map that had the most days correlated with it) and the number of cases or days that correlated with each base map. The surface weather maps corresponding to the geostrophic base map types derived by this procedure are reproduced in Appendix B. Appendix A lists types for the 4-year study period.

Air Quality Data Selection

In order to complete the objectives of this study, pollutant data from the St. Louis Regional Air Measurements (RAMS) network were correlated with the synoptic map types developed in this study, in an attempt to better understand the local and regional air pollution conditions. From all of the pollutant data collected by the RAMS network, five pollutants were chosen to accomplish this objective. These five pollutants were ozone (O_3), carbon monoxide (CO), total suspended particles (TSP), sulfate (SO_4) and nitrate (NO_3).

In the RAPS program, air quality data were collected from January 1975 through December 1976. Sampling for O_3 and CO was continuous and averaged on an hourly basis at all of the 25 RAM stations. High volume sampling was used for TSP, SO_4 , and NO_3 and 24-hour average samples were collected every third day at selected stations throughout the network.

Stations representative of the air quality of St. Louis central urban area were chosen from the 25 stations in the RAMS network depicted in Figure 2. For O_3 and CO, stations 101, 104, 105, 106, 107 and 110 were selected and for TSP, SO_4 and NO_3 , stations 103, 105, 106 and 108 were chosen. These stations were selected to provide an indication of the average concentrations of the pollutants across the central part of the St. Louis commercial and industrial area. It was expected that changes in synoptic conditions would have the most influence and thus be detected most readily in this part of the city since the concentrations tend to be maximized there.

Once the pollutant data were collected, they were classified and averaged by synoptic map types for each season for both the 850 mb and geostrophic map types. The ozone data were averaged by daily one hour maximum concentrations for the two year period 1975-1976. The one hour maximum concentration was chosen because there is a strong diurnal O_3 cycle, and it was concluded that the maximum value would be the best indicator of synoptic effects. The CO data were analyzed by daily average concentrations for the two year period. The daily average was used to minimize errors that could occur if a one hour value was used. The data for TSP, SO_4 and NO_3 were analyzed by 24 hr averages for every third day for the two year period.

To determine if there was a significant relationship between map types within a season certain statistical tests were applied to the stratified pollutant data. Since it was found that the pollutant data used in this study usually followed a log-normal distribution, and to ensure greater sensitivity throughout the analysis, the logarithms of the pollutant values as well as the basic pollutant data were used for the tests. Figure 3 shows the concentration and logarithmic concentration distributions for CO for the B (850F) map type. The figure shows that while the data are skewed to

Table 4. Summary of seasonal synoptic map types for geostrophic wind, 1973-1976.

Type	Winter (GeoW)		Spring (GeoSP)		Summer (GeoS)		Fall (GeoF)	
	Date of Base Map	No. of Cases $r \geq 0.65$	Date of Base Map	No. of Cases $r \geq 0.65$	Date of Base Map	No. of Cases $r \geq 0.65$	Date of Base Map	No. of Cases $r \geq 0.65$
A	Jan 17, 1973	68	May 6, 1973	74	July 16, 1975	78	Oct 29, 1974	90
B	Dec 17, 1975	57	March 7, 1975	37	July 3, 1974	41	Sept 9, 1976	60
C	Jan 29, 1973	30	April 4, 1975	41	July 11, 1974	37	Oct 2, 1974	33
D	Feb 7, 1976	21	March 18, 1976	33	July 4, 1976	21	Oct 2, 1975	24
E	Feb 19, 1974	22	March 12, 1976	20	Aug 8, 1974	25	Sept 24, 1974	19
F	Dec 14, 1975	18	April 7, 1974	21	July 27, 1973	22	Nov 9, 1976	16
G	Dec 18, 1973	24	May 12, 1975	17	July 24, 1975	18	Sept 15, 1976	14
H	Dec 23, 1975	13	March 7, 1973	12	July 8, 1973	16	Nov 23, 1974	14
I	Jan 25, 1976	19	May 27, 1973	10	Aug 14, 1976	13	Nov 23, 1973	17
Misc.		89		103		96		76
Total Typed		272		265		271		287
Total Cases		361		368		367		363
Percent Typed		75.4%		72%		73.9%		79.1%

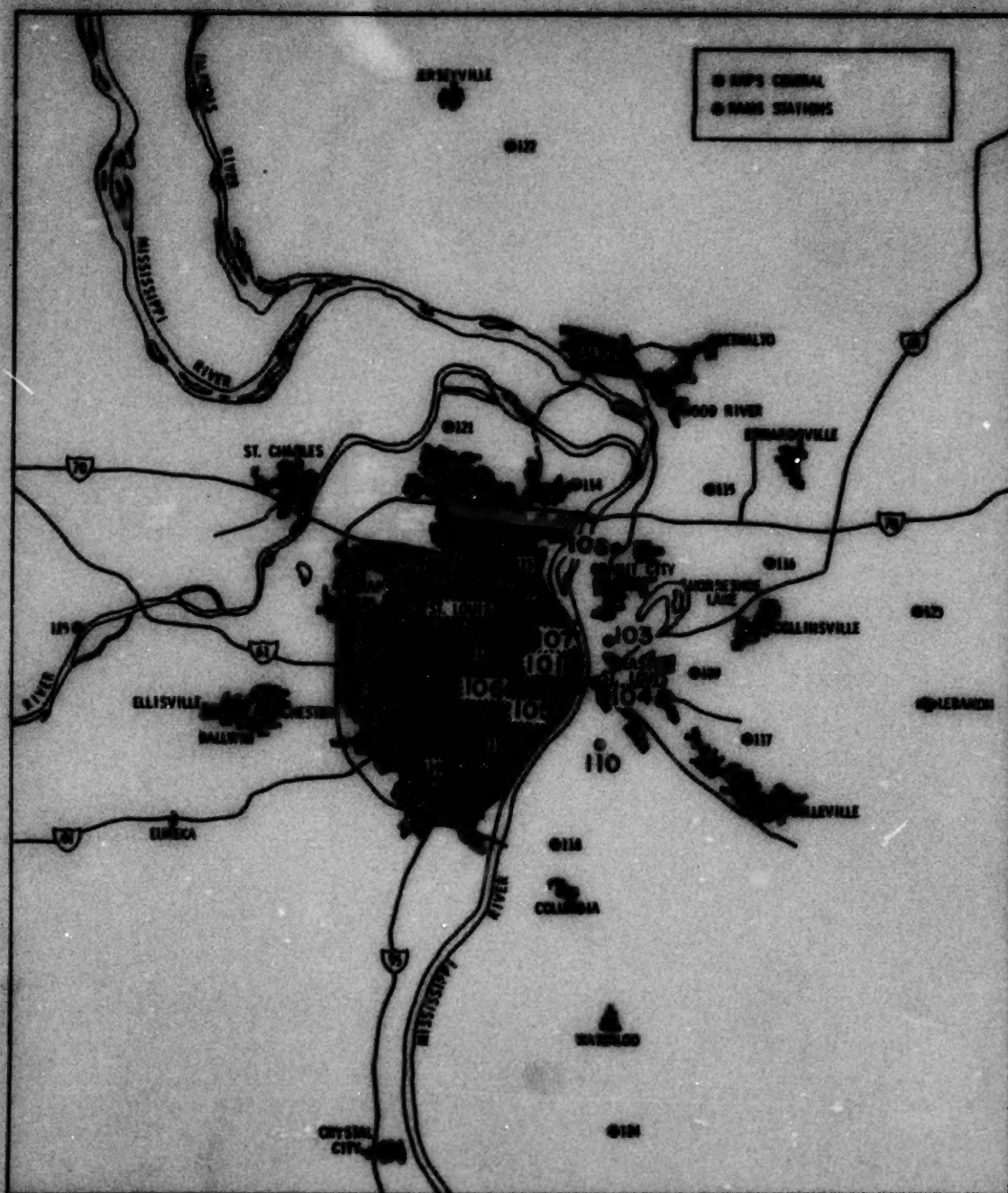


Figure 2. St. Louis Regional Air Pollution Study air monitoring network, 1975-76.

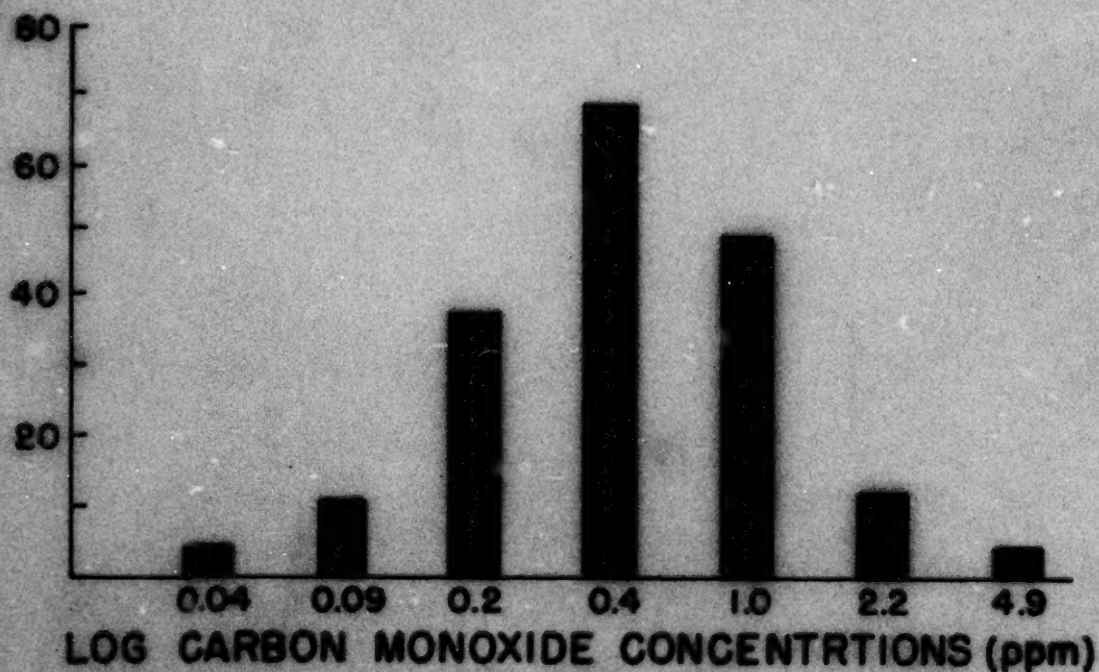
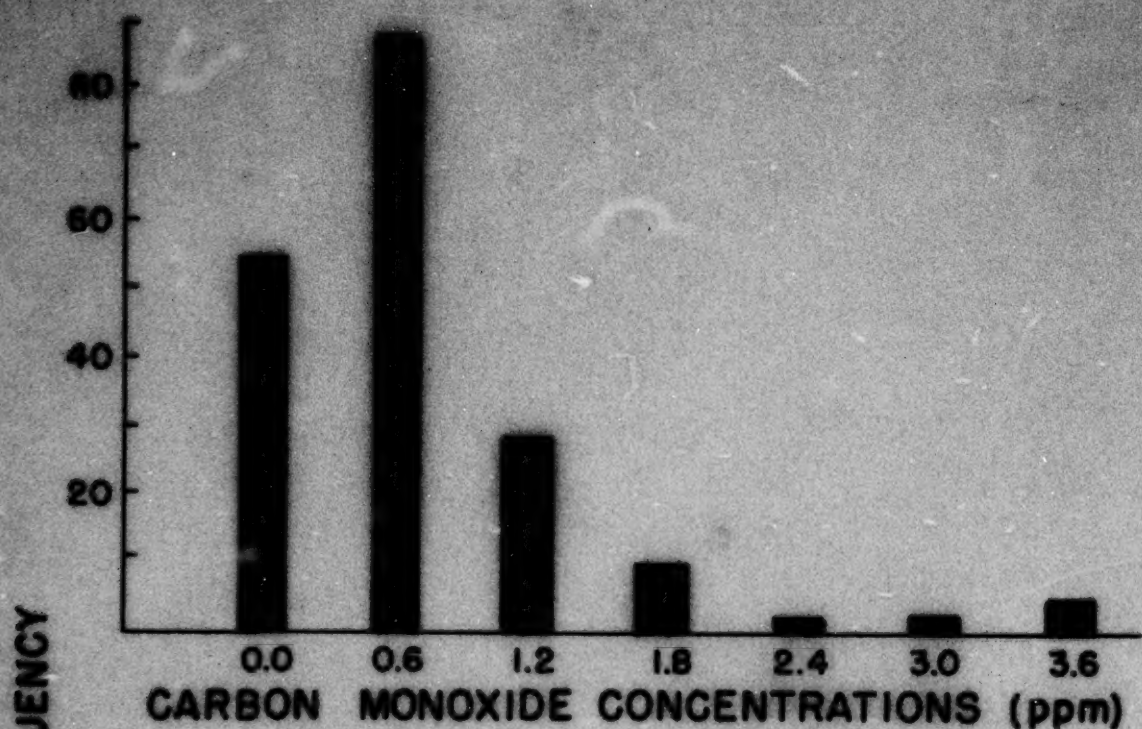


Figure 3. CO concentration and log concentration distributions for map type B(850F).

the lower values, by taking the log of the data, a more normal distribution results. Since most statistical tests handle normally distributed data better than skewed data, the statistical tests were applied to both the arithmetic and geometric means of the concentration data.

The first test performed on the pollutant data which had been stratified by map types for each season was an analysis of variance and a F test. For each pollutant, the mean concentration for one map type was compared to the mean concentrations for each of the remaining map types within the same season. The presence of significant differences between the concentrations for each type were determined by comparing the means for each map type. The results indicated that there were differences, and thus a more powerful statistical procedure, the Duncan's New Multiple Range test, was employed (Steel and Torrie, 1960). First, this tests compared the means for pairs of map types within a season, and determined if there were significant differences between the map types. Second, this test ranked the map types from higher to lower concentration, and third, it indicated which ones were significantly different from each other and which were not. Both the actual concentration data and the logarithms of the concentration data were used in this test.

Air Quality vs. 850 mb Map Types

A tabular ranking of seasonal map types by high to low concentrations of O_3 , CO, TSP, SO_4 , and NO_3 is given in Tables 5 through 9, which also shows the map types, number of station pollutant observations, mean concentrations, significant differences between map types, and remarks on the synoptic flow for each map type. Since there is a tendency for certain map types to identify with either higher or lower pollutant concentrations, some of the more important map types will be reviewed in the following discussion.

A close examination of the results listed in Tables 5 through 9, shows that the correlation with pollutant values mentioned above does exist for the 850 mb synoptic flow. Specifically, the results indicate that higher pollutant concentrations occur when there is a high pressure system present or when the flow is from the SW quadrant, while lower concentrations are related to low pressure systems or a northerly flow into St. Louis. This is shown by comparing the map types for each pollutant for each season and choosing the ones which correspond to high or low concentrations on a consistent basis.

For the winter season, map types A and C correlate with high pollutant concentrations while map type B is significantly lower for all of the pollutants analyzed except O_3 . This situation occurs because O_3 concentrations are at a background level for the winter season, and, as shown by Table 5 there is no significant difference between map types. However, map type C has a SSW flow into the St. Louis area and map type A has a westerly flow. Thus, these two elevated O_3 map types compare well with most of the map types for the spring, summer, and fall seasons which have the significantly higher mean O_3 concentrations. For example, map types D and E for the spring season; D and E for the summer season, and A, C, and F for the fall season all correspond to significantly higher pollutant concentrations

Table 5. Seasonal 850 mb map types ranked by ozone concentrations averaged for stations 101, 104, 105, 106, 107, 110.

Rank	Winter				Remarks	Type	Spring			Remarks
	Type	N	Conc	Sig			N	Conc	Sig	
1	B	170	22	none	north flow, low to ENE	E	43	71	2-6	calm wind, high to NE dominates
2	C	94	22	none	SSW flow, low to west	D	31	57	1,5	NE flow, low to E, high to NW
3	A	317	20	none	west flow, low to NE	A	238	51	1	WSW flow, low to NW, high to SE
4						B	183	50	1	SW flow, low to W, high to SE
5						C	196	47	1,2	NW flow, low to NE
6						F	16	47	1	Center of low pressure

Table 5. (Continued)

Rank	Summer					Fall				
	Type	N	Conc	Sig	Remarks	Type	N	Conc	Sig	Remarks
1	E	57	88	3-6	East flow, high to NNE	F	27	75	2-6	Calm winds, center of high
2	A	316	82	3-6	WSW flow, high to south	A	226	52	1,5,6	SW flow, high to south
3	C	136	77	1,2,4-6	SSW flow, high to east	C	149	50	1,5,6	SW flow, high to east
4	B	140	70	1-3,6	NW flow, low to NE	E	55	43	1,5,6	NE flow, low to NE, low winds
5	D	40	67	1-3,6	SW flow, low wind speeds	B	193	42	1-4,6	NW flow, high to west
6	F	39	55	1-5	NNW flow, low to NE	D	26	24	1-5	Center of low pressure

N = number of station observations

Conc = concentration in ppb

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

Table 6. Seasonal 850 mb map types ranked by carbon monoxide concentrations averaged for stations 101, 104, 105, 106, 107, 110.

Rank	Winter					Spring				
	Type	N	Conc	Sig	Remarks	Type	N	Conc	Sig	Remarks
1	C	77	2810	2,3	SSW flow, low to west	E	45	669	6	Calm wind, high to NE dominates
2	A	442	1145	1,3	West flow, low to NE	C	187	597	None	NW flow, low to NE
3	B	188	728	1,2	North flow, low to ENE	A	233	595	None	WSW flow, low to NW, high to SE
4						B	203	591	None	SE flow, low to W, high to SE
5						F	17	557	None	Center of low pressure
6						D	34	475	1	NE flow, low to E, high to NW

Table 6. (Continued)

Rank	Type	Summer			Remarks	Type	Fall			Remarks
		N	Conc	Sig			N	Conc	Sig	
1	E	66	885	2,4-6	East flow, high to NNE	F	28	2071	2-6	Calm winds, center of high
2	C	139	728	1,5,6	SSW flow, high to east	E	50	1042	1,4	NE flow, low to NE low winds
3	D	45	718	none	SW flow, low wind speed	A	201	888	1	SW flow, high to south
4	B	142	615	1	NW flow, low to NE	B	188	765	1,2	NW flow, high to west
5	A	320	603	1,2	WSW flow, high to south	C	149	765	1	SW flow, high to east
6	F	42	555	1,2	NNW flow, low to NE	D	26	684	1	Center of low pressure

N = number of station observations

Conc = concentration in ppb

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

Table 7. Seasonal 850 mb map types ranked by total suspended particle concentrations averaged for stations 103, 105, 106, 108.

Rank	Winter					Spring				
	Type	N	Conc	Sig	Remarks	Type	N	Conc	Sig	Remarks
1	A	161	122	2	West flow, low to NE	D	16	155	3-6	NE flow, low to E, high to NW
2	B	82	98	1	North flow, low to ENE	E	28	150	3-6	Calm winds, high to NE dominates
3	C	8	92	none	SSW flow, low to west	A	89	118	1,2	WSW flow, low to NW, high to SE
4						B	64	118	1,2	SW flow, low to W, high to SE
5						F	16	107	1,2	Center of low pressure
6						C	62	98	1,2	NW flow, low to NE

Table 7. (Continued)

Rank	Type	Summer			Remarks	Fall			Remarks
		N	Conc	Sig		Type*	N	Conc	
1	E	18	148	none	East flow, high to NNE	A	57	94	4,5 SW flow, high to south
2	C	68	147	6	SSW flow, high to east	C	36	93	4,5 SW flow, high to east
3	A	168	137	none	WSW flow, high to south	B	53	85	5 NW flow, high to west
4	B	44	122	none	NW flow, low to NE	E	14	65	1,2 NE flow, low to NE, low wind speed
5	F	8	122	none	NNW flow, low to NE	D	7	34	1-3 center of low pressure
6	D	20	110	2	SW flow, low wind speeds				

N = number of station observations

Conc = concentration in $\mu\text{g}/\text{m}^3$

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

*Type F (no data)

Table 8. Seasonal 850 mb map types ranked by sulfate concentrations averaged for stations 103, 105, 106, 108.

Rank	Winter					Spring				
	Type	N	Conc	Sig	Remarks	Type	N	Conc	Sig	Remarks
1	A	156	17	3	West flow, low to NE	D	16	25	4-6	NE flow, low to E, high to NW
2	C	8	15	none	SSW flow, low to west	F	14	21	6	Center of low pressure
3	B	82	13	1	North flow, low to ENE	E	28	19	6	Calm wind, high to NE dominates
4						B	65	16	1,6	SW flow, low to west, high to SE
5						A	82	15	1	WSW flow, low to NW, high to SE
6						C	54	12	1-4	NW flow, low to NE

Table 8. (Continued)

Rank	Type	Summer			Remarks	Type*	Fall			Remarks
		N	Conc	Sig			N	Conc	Sig	
1	E	18	35	3-6	East flow, high to NNE	C	69	19	4,5	SW flow, high to east
2	F	8	24	none	NNW flow, low to NE	A	132	19	4,5	SW flow, high to south
3	C	67	25	1,6	SSW flow, high to east	E	30	16	none	NE flow, low to NE, low wind speed
4	A	148	23	1,6	WSW flow, high to south	B	107	12	1,2	NW flow, high to west
5	D	20	21	1,6	SW flow, low wind speed	D	14	11	1,2	Center of low pressure
6	B	47	18	1,3-5	NW flow, low to NE					

N = number of station observations

Conc = concentration in $\mu\text{g}/\text{m}^3$

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

*Type F (no data)

Table 9. Seasonal 850 mb map types ranked by nitrate concentrations averaged for stations 103, 105, 106, 108.

Rank	Winter					Spring					Remarks
	Type	N	Conc	Sig	Remarks	Type	N	Conc	Sig		
1	C	8	9	2,3	SSW flow, low to west	E	28	7	3-6	Calm wind, high to NE dominates	
2	A	161	6	1	West flow, low to NE	D	16	7	3-6	NE flow, low to E, high to NW	
3	B	81	5	1	North flow, low to ENE	A	84	5	1,2,6	WSW flow, low to NW, high to SE	
4						C	62	5	1,2	NW flow, low to NE	
5						B	64	4	1,2	SW flow, low to W, high to SE	
6						F	16	3	1-3	Center of low pressure	

Table 9. (Continued)

Rank	Type	Summer			Remarks	Fall			Remarks
		N	Conc	Sig		Type*	N	Conc	
1	D	19	5	4-6	SW flow, low wind speeds	C	73	6	2-5 SW flow, high to east
2	A	154	5	4-6	WSW flow, high to south	A	125	5	1,3-5 SW flow, high to south
3	C	68	4	5,6	SSW flow, high to east	B	107	4	1,2 NW flow, high to west
4	B	48	3	1,2,6	NW flow, high to east	E	30	3	1,2 NE flow, low to NE, low wind speed
5	E	18	3	1-3	East flow, high to NNE	D	14	2	1,2 Center of low pressure
6	F	8	1	1-4	NNW flow, low to NE				

N = number of station observations

Conc = concentration in $\mu\text{g}/\text{m}^3$

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

*Type F (no data)

and all have flows from the SW quadrant or flows indicative of the presence of a high pressure system.

Figures 4, 5, and 6 show the 850 mb patterns for map types E (850S), E (850SP), and A (850F), respectively. Map type E (850S), Figure 4, correlates with generally elevated pollutant concentrations, ranking first in the summer season for O_3 , CO, TSP, and SO_4 while ranking only fifth for NO_2 . The weather pattern associated with this map type, as indicated by Figure 4, is dominated by a large high covering most of the area east of the Rocky Mountains. The high center is north of St. Louis over the Great Lakes. Winds into the St. Louis area are generally from the easterly gradient with relatively weak speeds of about kts.

Map type E (850SP), Figure 5, is an elevated pollutant type for the spring season. It was ranked first for O_3 , CO, and NO_2 , and it was not significantly different in average concentration from the highest ranked map types for TSP and SO_4 . The synoptic pattern near St. Louis for this map is influenced by a broad weak ridge between east coast and west coast low centers. The St. Louis area is generally in a cold region with light and variable winds. Figure 6 shows the 850 mb flow for map type A (850F). This fall map type was ranked first for TSP and SO_4 , and was ranked second for O_3 , CO and NO_2 . The 850 mb flow is from the SW quadrant with moderate 30 to 40 kt wind speeds. A high pressure system is to the SE and is still dominating the synoptic pattern. Note the trough west of St. Louis, along the Rockies. The contour interval is 60 m for this map compared to 30 m for Figures 4 and 5.

As previously mentioned, the only exception to the occurrence of higher pollutant concentrations with the presence of a high pressure system or a SW flow occurs during the winter season for O_3 concentrations, however this is not considered important since there is no significant difference between any of the winter map types when related to O_3 . This is due to the generally low levels of O_3 which result from the limitation of photochemical processes because of limited amounts of solar radiation during this season.

The lower average concentrations of pollutants occurred with 850 mb patterns favoring flow from the north or with the presence of a low pressure system. This is seen by comparing the map types which correlated with the minimum mean concentration for each pollutant for each season. For the winter season, map type B with a northerly flow into St. Louis had a significantly lower pollutant concentration. Similarly, map types C and F for spring; map types B and F for summer; and map types B and D for the fall had significantly lower mean concentrations with flows from the northerly direction or the presence of a low pressure system. Figures 7 and 8 show the 850 mb flows associated with lower pollutant concentrations for map types D-fall and F-summer, respectively. From both figures, it is clear that a low pressure trough dominates the St. Louis region. The wind speeds are generally in the 25 to 30 kt range. Since the presence of low pressure systems are usually associated with unstable air, cloud cover, and possible precipitation, the type of synoptic patterns shown in Figures 7 and 8 are expected to correspond with lower pollutant concentrations. The only exception to lower pollutant concentrations correlating with a north wind or a low pressure system occurs

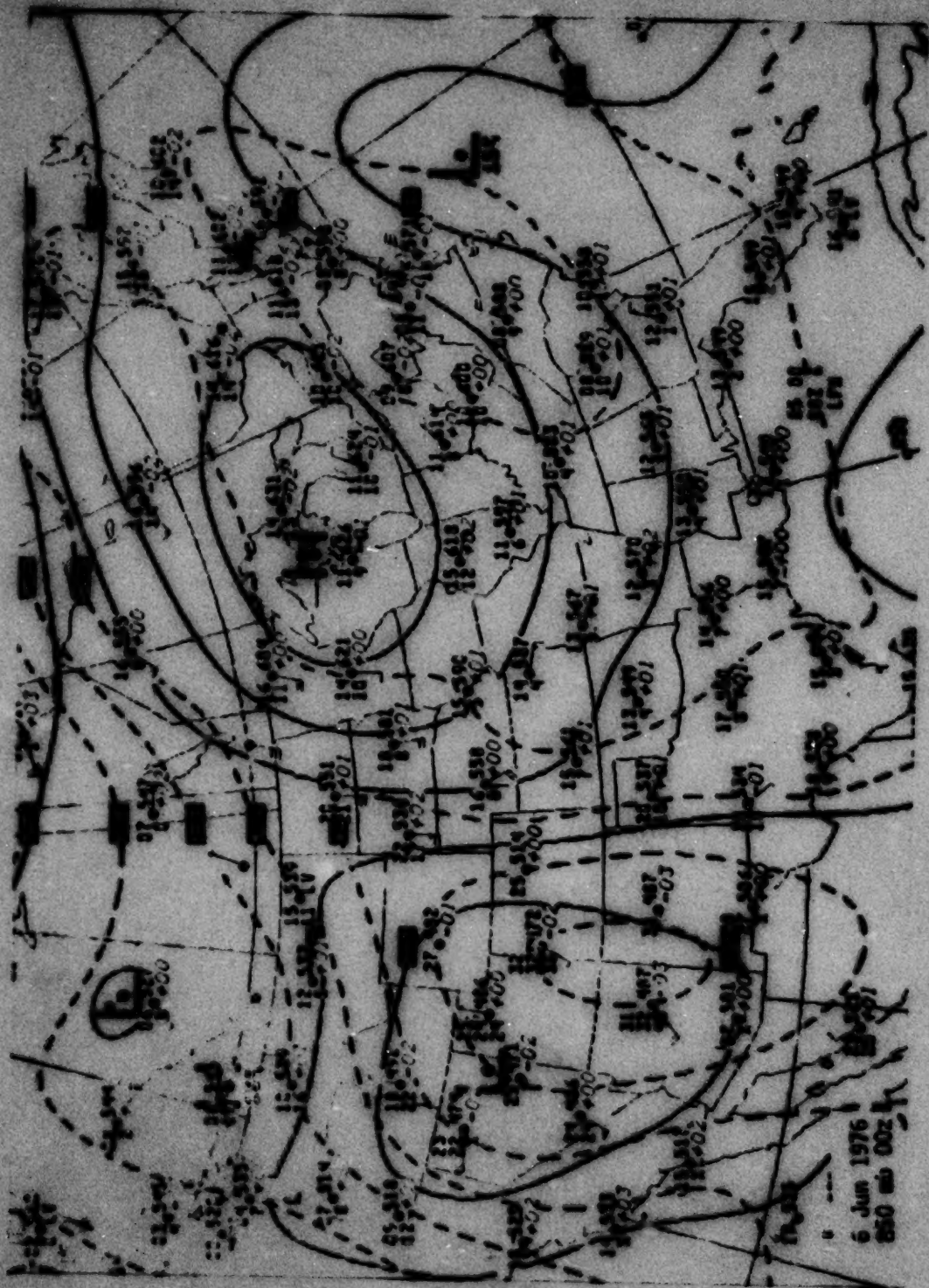


Figure 4. Synoptic analysis for map type E(850S), June 6, 1976.

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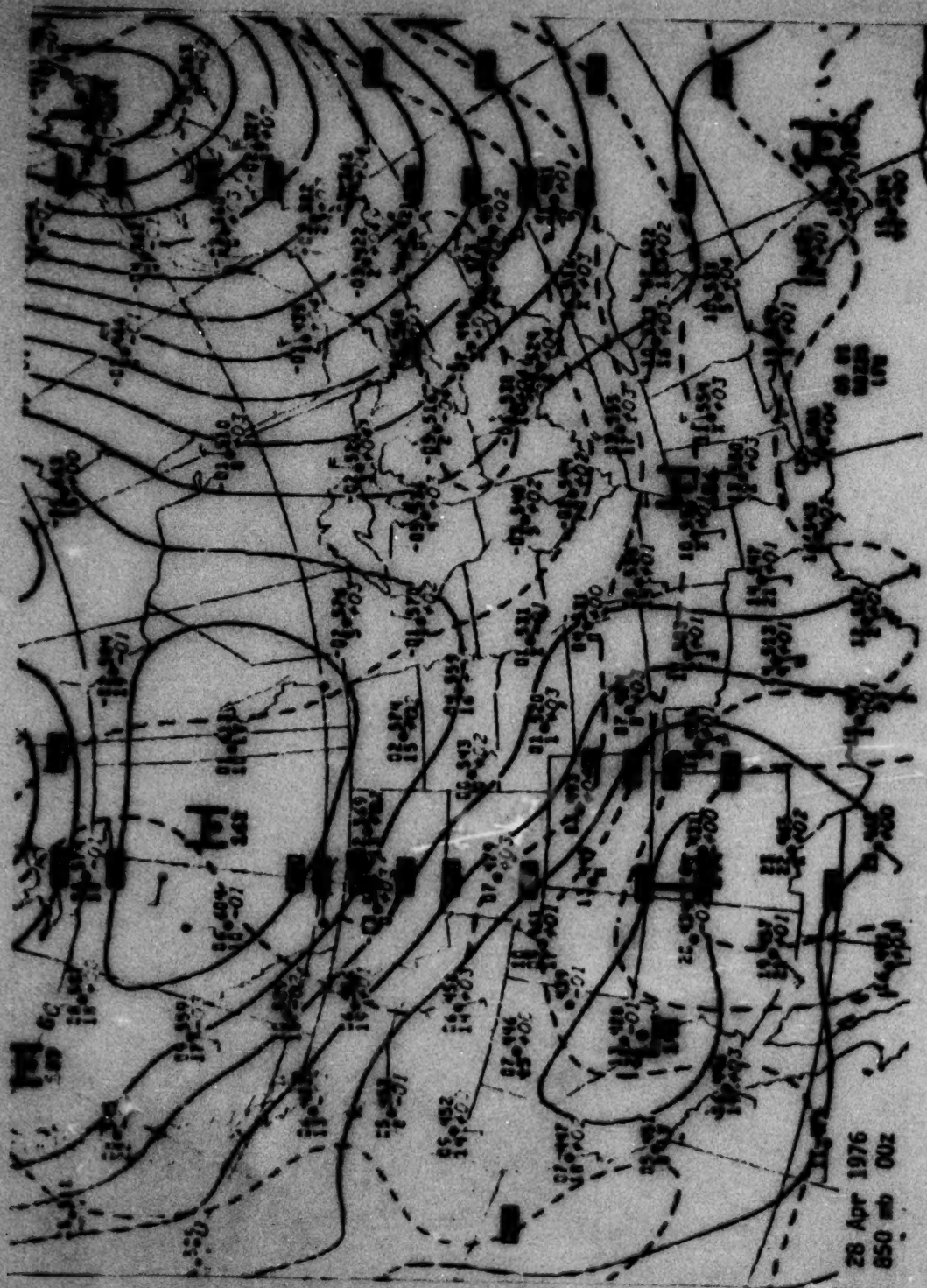


Figure 5. Synoptic analysis for map type E(850SP), April 28, 1976.

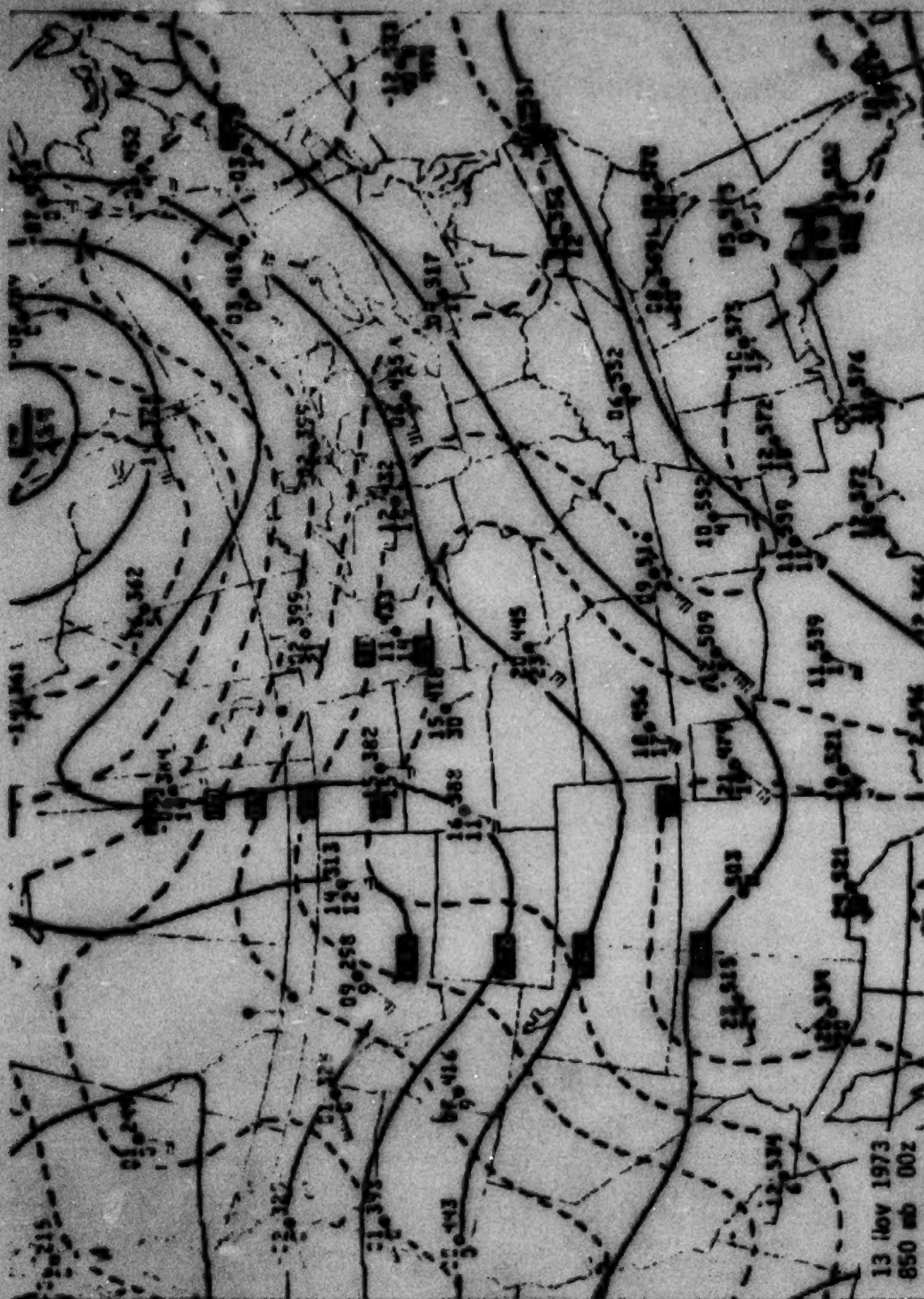


Figure 6. Synoptic analysis for map type A(850F), November 13, 1973.

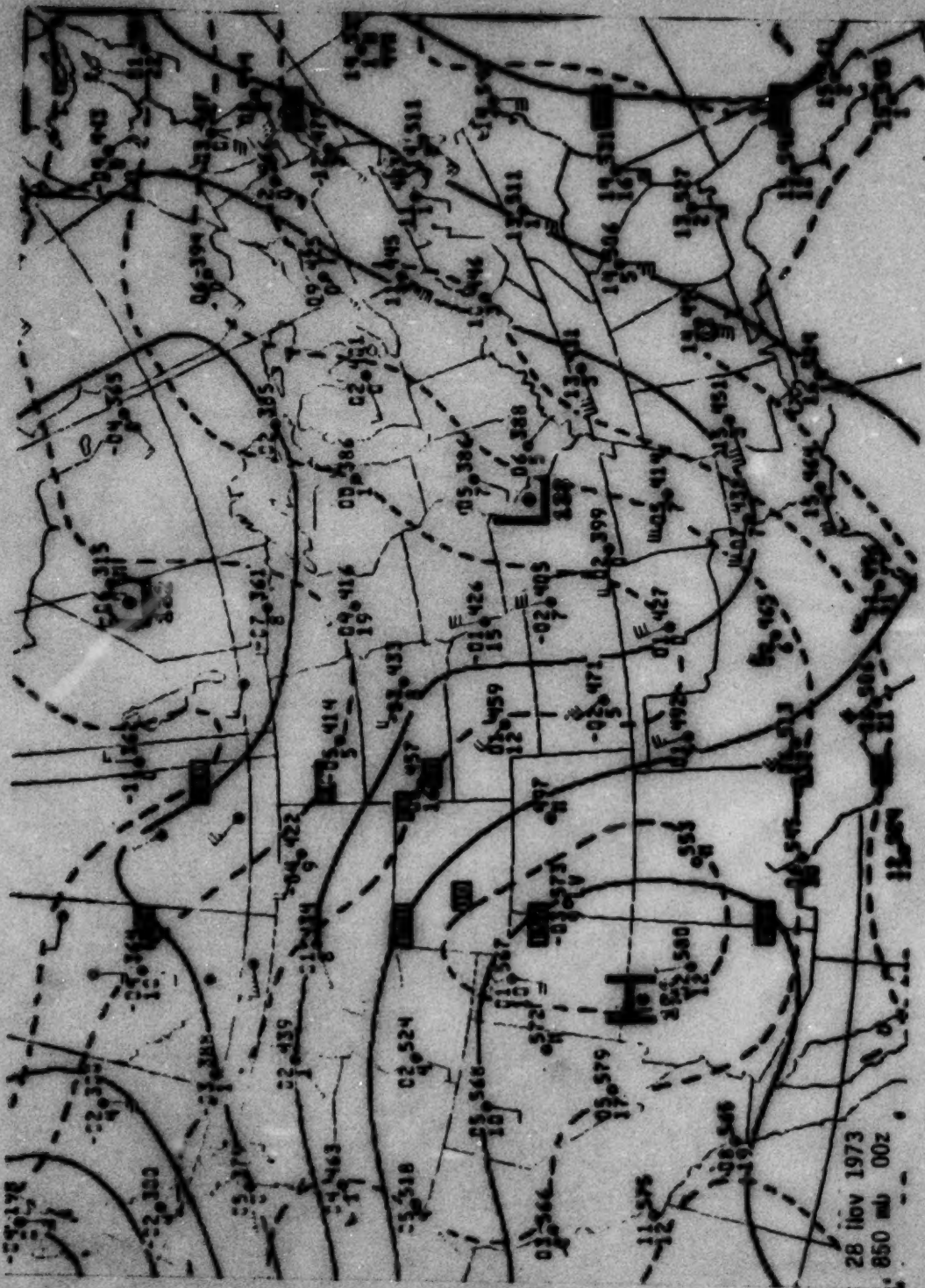


Figure 7. Synoptic analysis for map type D(850F), November 28, 1973.

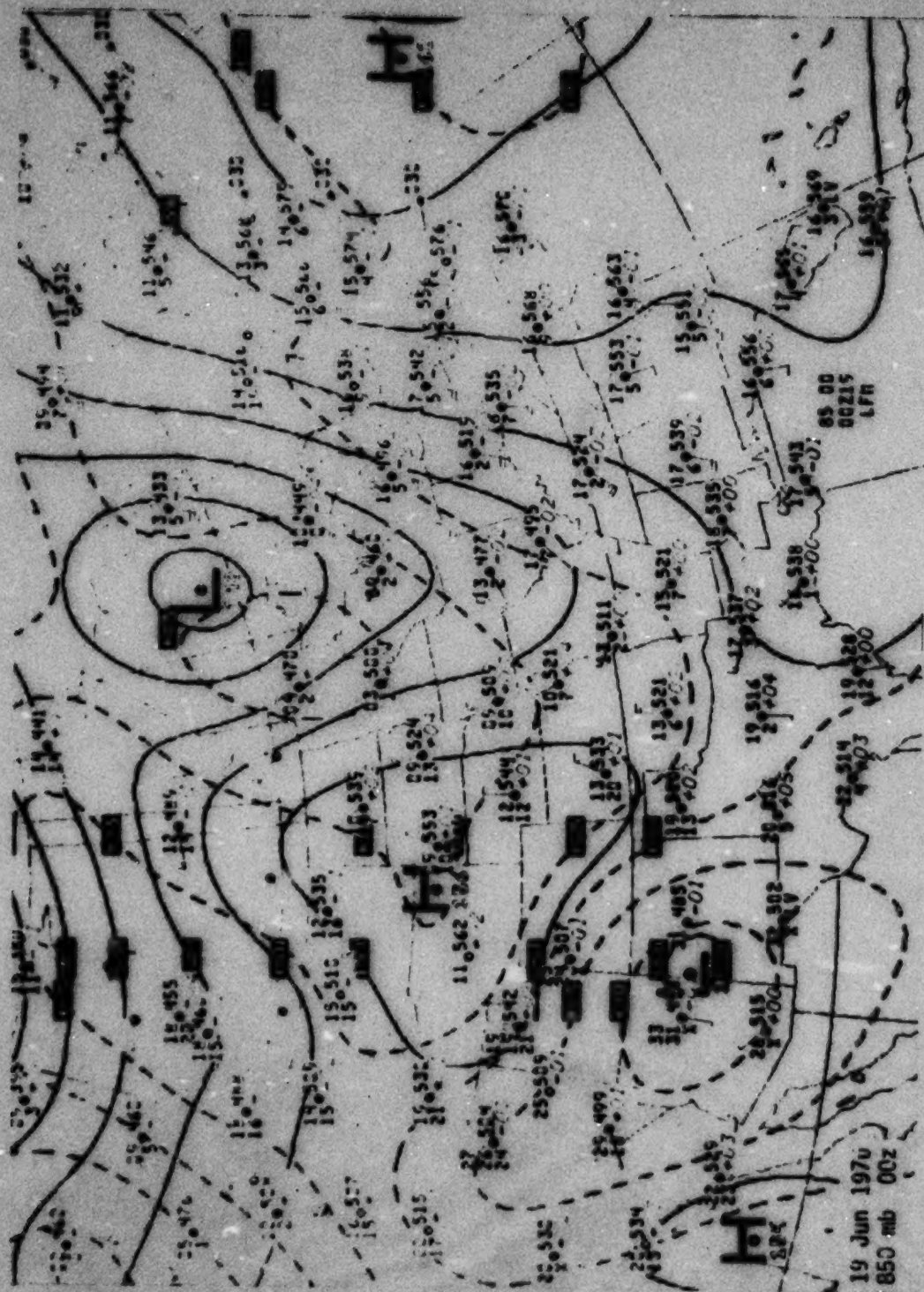


Figure 8. Synoptic analysis for map type F(850S), June 19, 1976.

with total suspended particles during the summer season; in this case map type D (850S) with a SW flow had the lowest mean TSP concentration.

There is also a tendency for higher and lower average concentrations to have a seasonal cycle, but the cycle varies depending on the pollutant. For O_3 , the higher mean concentrations occurred during the summer and the lower mean concentrations occurred during the winter. This is expected since there is a decrease in photochemical processes during the winter months.

Both CO and NO_3 had higher mean concentrations during the winter than any other time of the year. This is believed to be due to the expected increase in combustion and heating activity during the winter and also to the presence of radiation inversions and stagnation which are frequent during this time. With regard to SO_4 , higher concentrations occurred during the summer and lower concentrations throughout the rest of the year. This is considered to be indicative of photochemical reactions involving SO_2 , and has been noted in other studies (Hidy, et al. 1978). The highest TSP concentrations occurred during the summer and the lowest during the fall. This probably indicates the increased probability of local resuspension of dust during the summer months when roads and other dust sources are more likely to be dry. Average summertime winds are 20 to 30% lighter than winter surface winds so except in summer convective storms resuspension by wind is probably more related to surface conditions.

Air Quality vs. Geostrophic Wind Map Types

A tabular ranking of seasonal map types by high to low concentrations of O_3 , CO, TSP, SO_4 and NO_3 is illustrated in Tables 10 through 14. These tables show the map types, number of station pollutant observations, mean concentrations, significant differences between map types, and remarks concerning the synoptic flow for each map type. Examination of the results listed in these tables shows that there is a tendency for pollutant concentrations to be classified according to certain geostrophic map types. As with the other analysis, the results indicate that higher pollutant concentrations occur when there is a high pressure system present or when the flow is from the SW quadrant, while lower concentrations are related to low pressure systems in the region around St. Louis. These results are similar to the ones determined from the 850 mb map type analysis. However, the tendency for higher or lower concentrations to stratify by map types is less clearly defined for the geostrophic wind types than for the 850 mb flows. This is attributed to the fact that the 850 mb patterns are divided into only six pressure distributions for each season, while the pollutant correlations with the geostrophic wind are divided among nine map types. As one example of how the flow becomes more complex, a flow from a single direction could be divided into two distinct map types for the geostrophic wind due to differences in wind speed while only one 850 mb map type would probably be identified. Another factor that makes the geostrophic pattern less satisfactory is that each pair of stations defines only a component of the wind normal to the line between the stations. This component may not be a close approximation to the actual wind.

Table 10. Seasonal geostrophic map types ranked by ozone concentrations averaged for stations 101, 104, 105, 106, 107, 110.

Winter						Spring				
Rank	Type	N	Conc	Sig	Remarks	Type	N	Conc	Sig	Remarks
1	I	38	34	2-9	Center of high pressure	H	37	58	3-9	South flow, low to SW
2	F	57	27	1,6-9	SE flow, high to NE	G	54	52	6-9	Calm winds, high to NW
3	G	47	26	1,8,9	SE flow, high to NE	C	141	51	1,6-9	Center of high pressure
4	D	57	24	1,8,9	Center of high	D	76	50	1,7-9	SW flow, high to SE
5	E	41	22	1,8,9	South flow, low to SW	A	122	49	1,7-9	SE flow, low to west, high winds
6	C	74	21	1,2,8,9	NW flow, high to west	E	49	44	1-3	SE flow, low to W, high wind speeds
7	A	175	21	1,2,8,9	SW flow, low to SW	I	26	39	1-5	SE flow, low to SW
8	B	130	16	1-7	Center of low	B	83	39	1-5	SE flow, low directly west
9	H	38	12	1-7	NE flow, high to NW	F	49	37	1-5	South flow, high to SE, low to west

Table 10. (Continued)

Rank	Summer				Remarks	Fall				Remarks
	Type	N	Conc	Sig		Type	N	Conc	Sig	
1	B	82	83	8,9	SSW flow, low to west	G	43	75	4-9	South flow, low winds
2	G	33	82	9	Calm winds, center of high	I	30	72	4-9	High pressure
3	C	117	82	8,9	South flow, low wind speeds	H	33	61	5-9	SE flow, high to east
4	A	192	81	8,9	South flow, high to NE	C	79	56	1-2,5-9	ENE flow, high to NW
5	I	34	79	none	SE flow, high to NE	A	218	45	1-4,9	SE flow, high to NE
6	E	60	76	none	SE flow, high to NE	E	51	40	1-4	SE flow, high to NE, low winds
7	H	30	72	none	South flow, high to SE	F	47	40	1-4	SW flow, high to south, low winds
8	F	46	69	1,3,4	WNW wind, low to north	D	58	38	1-4	North flow, high to west
9	D	63	69	1-4	East flow, high to NW dominates	B	160	34	1-5	SE flow, high to east

N = number of station observations

Conc = concentration in ppb

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

Table 11. Seasonal geostrophic map types ranked by carbon monoxide concentrations averaged for stations 101, 104, 105, 106, 107, 110.

Rank	Winter				Remarks	Spring				
	Type	N	Conc	Sig		Type	N	Conc	Sig	Remarks
1	H	30	1933	8,9	NE flow, high to NW	F	42	848	2-9	South flow, high to SE, low to west
2	B	109	1870	8,9	Center of low	C	127	636	1,9	Center of high
3	A	165	1804	8,9	SW flow, low to SW	B	81	613	1,9	SE flow, low directly west
4	G	41	1695	none	SE flow, high to south	D	79	584	1	SW flow, high to SE
5	I	36	1443	none	Center of high pressure	I	25	571	1	SE flow, low to SW
6	D	53	1329	none	Center of high	H	39	569	1	South flow, low to SW
7	C	65	1286	none	NW flow, high to west	A	139	552	1	SE flow, low to west, high winds
8	F	57	1007	1-3	SE flow, high to NE	G	54	524	1	Calm winds, high to NW
9	E	54	1005	1-3	South flow, low to SW	E	49	458	1-3	SE flow, low to W, high wind speeds

Table 11. (Continued)

Rank	Summer				Remarks	Type	Fall				Remarks
	Type	N	Conc	Sig			N	Conc	Sig		
1	G	37	805	7-9	Calm wind, center of high	I	31	1535	2-9		High pressure
2	I	36	783	9	SE flow, low to SW	C	138	1017	1,9		ENE flow, high to NW
3	A	202	719	9	South flow, high to NE	A	200	953	1,9		SE flow, high to NE
4	B	87	663	none	SSW flow, low to west	E	52	943	1		SE flow, high to NE, low winds
5	C	127	651	none	South flow, low wind speeds	H	34	898	1		SE flow, high to east
6	D	65	630	none	East flow, high to NW dominate	F	45	859	1		SW flow, high to south, low winds
7	E	58	619	1	SE flow, high to NE	D	63	826	1		North flow, high to west
8	H	34	590	1	South flow, high to SE	G	41	747	1		South flow, low winds
9	F	57	585	1-3	WNW flow, low to north	B	168	740	1-3		SE flow, high to east

N = number of station observations

Conc = concentration in ppb

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

Table 12. Seasonal geostrophic map types ranked by total suspended particle concentrations averaged for stations 103, 105, 106, 108.

Rank	Type*	Winter				Remarks	Type	Spring			Remarks
		N	Conc	Sig	Sig			Conc	Sig		
1	D	6	136	none	Center of high	G	8	183	4-9		Calm winds, high to NW
2	A	60	122	7-8	SW flow, low to SW	I	16	146	none		SE flow, low to SW
3	I	16	113	none	Center of high	H	8	127	none		South flow, low to SW
4	F	24	105	none	SE flow, high to NE	C	54	126	1		Center of high
5	B	48	102	none	Center of low	B	32	121	1		SE flow, low directly west
6	H	14	87	none	NE flow, high to NW	A	74	116	1		SE flow, low to west, high winds
7	E	20	87	2	South flow, low to SW	D	36	107	1		SW flow, high to SE
8	C	32	81	2	NW flow, high to west	E	20	102	1		SE flow, low to W, high wind speeds
9						F	9	95	1		South flow, high to

Table 12. (Continued)

Rank	Type	Summer			Remarks	Fall			Remarks
		N	Conc	Sig		Type*	N	Conc	
1	B	28	148	9	SSW flow, low to west	I	8	217	4-9 High Pressure dominates
2	E	54	147	9	SE flow, high to NE	H	8	204	5-9 SE flow, high to east
3	A	96	146	7,9	South flow, high to NE	G	24	165	6-9 South flow, low to east
4	G	20	144	9	Calm winds, center or high	C	33	159	1,6-9 ENE flow, high to NW
5	I	21	142	9	SE flow, low to north	F	24	128	1,2 SW flow, high to south, low winds
6	F	30	135	none	WNW flow, low to north	D	34	115	1-4 North flow, high to west
7	C	46	122	3	South flow, low wind speeds	B	105	114	1-4 SE flow, high to east
8	D	20	118	none	East flow, high to NW dominates	A	121	109	1-4 SE flow, high to NE
9	H	24	101	1-5	South flow, high to SE	E	8	83	1-4 SE flow, high to NE, low winds

N = number of station observations

Conc = concentration in $\mu\text{g}/\text{m}^3$

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

*Type G (no data)

Table 13. Seasonal geostrophic map types ranked by sulfate concentrations averaged for stations 103 105, 106, 108.

Rank	Winter					Spring					Remarks
	Type	N	Conc	Sig	Remarks	Type	N	Conc	Sig		
1	H	14	16	7,8	NE flow, high to NW	G	8	35	2-9	Calm winds, high to NW	
2	B	48	16	7,8	Center of low	I	16	23	1,4-9	SE flow, low to SW	
3	A	61	15	7,8	SW flow, low to SW	H	8	17	1	South flow, low SW	
4	D	6	14	none	Center of high	B	32	16	1,2	SW flow, low directly west	
5	I	16	14	none	Center of high	A	74	16	1,2	SE flow, low to west, high winds	
6	E	20	12	none	South flow, low to SW	C	54	14	1,2	Center of high	
7	E	24	11	1-3	SE flow, high to NE	E	20	14	1,2	SE flow, low to W, high winds	
8	C	32	10	1-3	NW flow, high to west	D	36	13	1,2	SW flow, high to SE	
9						F	10	11	1,2	South flow, high to SE, low to west	

Table 13. (Continued)

Rank	Summer				Remarks	Type	Fall			Remarks
	Type	N	Conc	Sig			N	Conc	Sig	
1	B	28	32	5-9	SSW flow, low to west	H	8	29	3-9	SE flow, high to east
2	A	88	27	8,9	South flow, high to NE	G	24	25	3-9	South flow, low winds
3	I	22	27	9	SE flow, low to SW	C	37	20	1,2,4, 5,7-9	ENE flow, high to NW
4	E	54	26	8,9	SE flow, high to NE	D	34	16	1-3,8,9	North flow, high to west
5	C	46	21	1	South flow, low wind speeds	A	121	16	1-3,8,9	SE flow, high to NE
6	H	28	21	1	South flow, high to SE	I	8	15	1,2	High pressure dominates
7	G	20	20	1	Calm winds, center of high	E	8	12	1-3	SE flow, high to NE, low winds
8	F	30	16	1,2,4	WNW wind, low to north	F	24	11	1-5	SW flow, high to south, low winds
9	D	20	12	1-4	East flow, high to NW	B	110	10	1-5	SE flow, high to east

N = number of station observations

Conc = concentration in $\mu\text{g}/\text{m}^3$

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

*Type G (no data)

Table 14. Seasonal geostrophic map types ranked by nitrate concentrations averaged for stations 103, 105, 106, 108.

Rank	Type*	Winter			Remarks	Type	Spring			Remarks
		N	Conc	Sig			N	Conc	Sig	
1	I	16	8	6-8	Center of high	G	8	7	8,9	Calm winds, high to NW
2	D	6	8	7,8	Center of high	A	74	7	7-9	SE flow, low to west, high winds
3	H	14	7	7,8	NE flow, high to NW	B	32	7	7-9	SE flow, low to west
4	B	48	6	6-8	Center of low	C	54	6	8,9	Center of high
5	A	60	6	6-8	SW flow, low to SW	I	16	4	2	SE flow, low to SW
6	F	24	4	1,4,5	SE flow, high to NE	H	8	4	none	South flow, low to SW
7	C	24	3	1-5	NW flow, high to west	E	20	4	2,3	SE flow, low to W, high winds
8	E	20	3	1-5	South flow, low to SW	D	36	4	1-4	SW flow, high to SE
9						F	10	2	1-4	South flow, high to SE, low to west

Table 14. (Continued)

Rank	Type	Summer			Remarks	Type	Fall			Remarks
		N	Conc	Sig			N	Conc	Sig	
1	I	21	6	4-9	SE flow, low to SW	H	8	9	6-9	SE flow, high to east
2	B	28	5	7-9	SSW flow, low to west	E	8	8	6-9	SE flow, high to NE. low winds
3	G	20	5	9	Calm winds, center of high	C	37	7	6-9	ENE flow, high to NW
4	A	92	5	1,7-9	South flow, high to NE	G	24	6	7-9	South flow, low winds
5	E	54	4	1,9	SE flow, high to NE	I	8	6	9	High pressure dominates
6	D	20	3	1	East flow, high to NW dominates	D	34	5	1-3	North flow, high to west
7	F	30	3	1,2,4	WNW wind, low to north	A	121	5	1-4,9	SE flow, high to NE
8	H	28	3	1,2,4	South flow, high to SE	F	24	4	1-4	SW flow, high to south, low winds
9	C	46	3	1-5	South flow, low wind speeds	B	105	4	1-5,7	SE flow, high to east

N = number of station observations

Conc = concentration in $\mu\text{g}/\text{m}^3$

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

*Type G (no data)

Analysis of the results of the statistical tests applied to the geostrophic map types for pollutant concentrations shows that higher pollutant concentrations repeatedly correlate with map types A, B, H and I for the winter season; G for the spring season; B and G for the summer season; and I and G for the fall season. Lower pollutant concentrations occur with map types E and C for winter; E and F for spring; H, F and D for summer; and B and D for fall. These results show that, except for spring, two or more map types were associated with similar pollutant concentrations for a season. For the spring season map type G generally corresponded to higher pollutant concentrations.

Figures 9, 10, and 11 show the surface flows related to the geostrophic map types B(GeoS), G(GeoSP), and I(GeoF), respectively. Map type B(GeoS) shown in Figure 9 repeatedly correlated with higher pollutant concentrations, ranking first for O_3 , TSP and SO_4 while being insignificantly different from the map type with the highest mean concentration for CO and NO_3 . Figure 9 shows that the flow into St. Louis from the SSW direction results from a low pressure system to the west, and the large high centered off the South Carolina coast. The pressure gradient over the region is well developed resulting in south southwesterly flow and surface wind speeds of 5 to 15 kts. Skies were generally clear to scattered clouds.

Figure 10 shows the surface weather pattern for May 12, 1975, the base map for map type G(GeoSP). This map type was strongly correlated with high concentrations for all of the pollutants except CO. Although the isobaric pattern is complex, the characteristic feature of this pattern seems to be the large area of high pressure to the northwest, north, and southwest of St. Louis and the large area of almost negligible pressure gradient west of the city. A weak frontal system lies through the Great Lakes. The very weak pressure gradient around St. Louis contributes to weak geostrophic flow and the predominance of local effects.

Map type I(GeoF), as shown by Figure 11, is similar to map type G(GeoSP), with a high pressure system north of St. Louis along with a weak frontal system. However, in Type I(GeoF) there is another well developed high pressure system to the east that is also influencing the flow. The resulting wind flow is from the south at first, later changing to the north as the high moves into the area from the west.

Average pollutant concentrations were generally lower when there was a low pressure system affecting the area. Lower concentrations also occurred with the presence of a high pressure system with strong winds. This is evident in Figures 12, 13 and 14 which show map types C(GeoW), D(GeoF) and F(GeoSP), respectively.

Map type C(GeoW) in Figure 12 corresponds to the lowest mean concentrations for TSP, SO_4 and NO_3 and to relatively low concentrations for O_3 and CO. The wind flow is from the north due to a low pressure system to the east and a high to the west. The lower concentrations are attributed to the strong winds and the presence in the low pressure systems of precipitation and increased turbulent mixing. Figure 13 shows the surface



Figure 9. Synoptic analysis for map type B(GeoS), July 3, 1974.



Figure 10. Synoptic analysis for map type G(GeoSP), May 12, 1975.



Figure 12. Synoptic analysis for map type C(GaM), January 29, 1973.

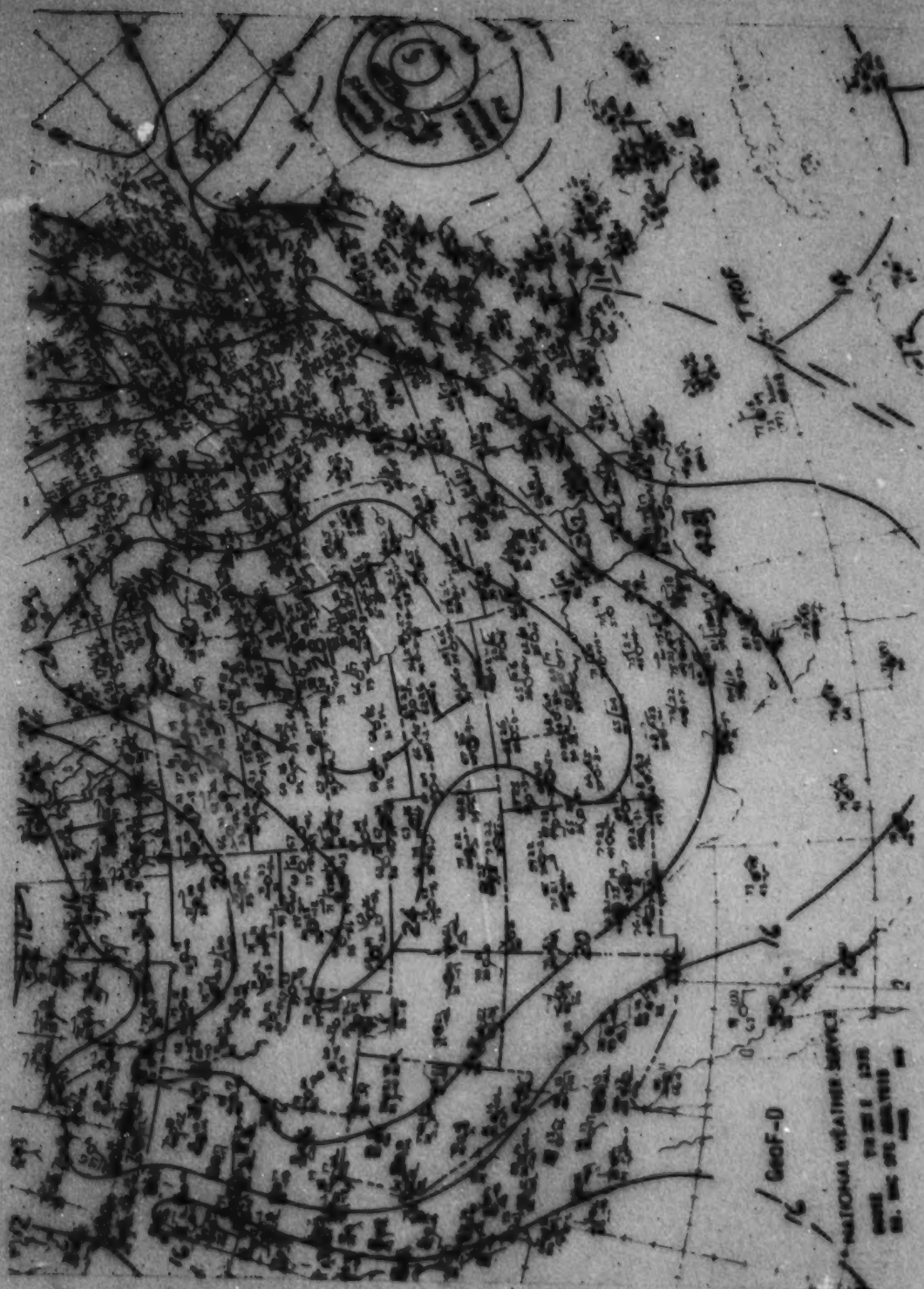


Figure 13. Synthetic analysts for map type D(Gaof), October 2, 1975.

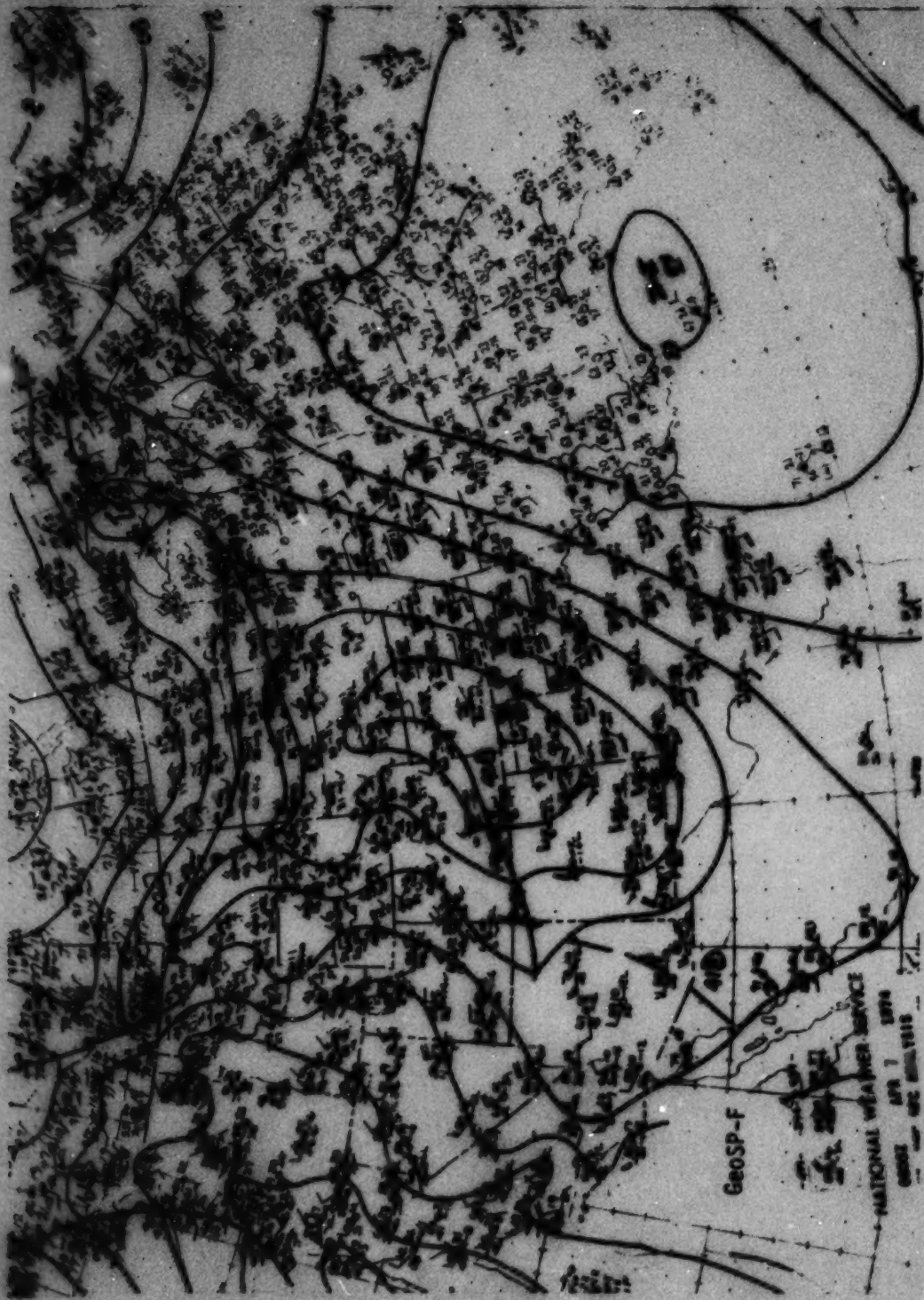


Figure 14. Synoptic analysis for map type F(GeoSP), April 7, 1974.

weather pattern for map type D(GeoF). The figure shows that a frontal system recently moved through the region and a cold high is moving into the area. The winds are light, 5 to 10 kts, from the north. This type of pattern would be expected to be replaced by patterns with stronger anticyclonic influence and generally higher pollutant concentrations. This was generally the case with the D(GeoF) base map of October 2, 1975 which, as shown by Appendix A-2, was followed by map types E(GeoF) and C(GeoF). Tables 10-14 show that these had generally higher concentrations than D(GeoF). Figure 14 shows the surface flows associated with map type F(GeoSP). This map type is associated with the lowest concentrations for O_3 , TSP, SO_4^{2-} and NO_3^- , but had the highest concentration for CO. The map pattern shows that the strong wind flow from the south is caused by a high to the SE and a low pressure system to the west of St. Louis. The steep pressure gradient between these systems results in wind speeds of 10 to 20 kts. The lower pollutant concentrations are attributed to the increasing wind speeds with the approach of the trough to the west and the increasing instability expected with this system.

Comparison of 850 mb, Geostrophic, and Surface Map Typing Schemes

From this study and the study by Robinson and Boyle (1980), a total of three different sets of map types was developed and compared with air quality data--namely the surface level, the 850 mb level, and a component pattern related to the geostrophic wind. The three sets of map types were examined on the basis of their performance in stratifying pollutant data into useful concentration classes. The following discussion compares the results of an air quality analysis by map type using the three sets of map types. The discussion is limited to the pollutants O_3 , CO, and TSP, for which data are available for all three map typing procedures. Robinson and Boyle (1980) analyzed the surface map types using mean concentrations for CO and TSP, and their results will be used in this comparison. Maximum daily ozone concentrations were analyzed as a part of this study using Robinson and Boyle's surface map types, and the results are given in Table 15. As before this table provides a ranking of seasonal maps by high to low O_3 concentrations, and includes the number of station pollutant observations, mean concentration, significant differences between map types, and remarks concerning the synoptic flow for each map type. The results for the surface analysis are similar to the results from the 850 mb and geostrophic analysis for O_3 , and show generally a tendency for O_3 concentrations to stratify by map types.

The data also show that the stratification of the surface map types by higher to lower ozone concentrations is not as clear cut as it is for either the 850 mb or the geostrophic map types. This is seen by comparing the results from the 850 mb and geostrophic wind analysis, listed in Tables 5 and 10, respectively, to those illustrated in Table 15 for ozone concentrations during the summer months. The summer season is a good test period because ozone concentrations are maximum during this season and the synoptic systems have the greatest effect on the ozone concentrations during the summer.

The 850 mb analysis, (Table 5) indicates that map types E and A for the summer season have significantly higher mean O_3 concentrations of 88 and 82 ppb, respectively, and these are statistically different from the other 4

Table 15. Seasonal surface map types ranked by ozone concentrations averaged for stations 101, 104, 105, 106, 107, 110.

Rank	Type*	Winter				Remarks	Type	Spring				Remarks
		N	Conc	Sig				N	Conc	Sig		
1	K	27	29	10-12	South flow.	M	11	68	6-12		High center	
2	A	154	24	none	High center	B	136	56	6-12		South flow	
3	L	11	24	none	SW flow	D	95	56	6-12		South flow	
4	C	118	23	none	High center	F	46	54	10-12		South flow	
5	I	26	23	none	SE flow	H	86	53	9-12		NE flow	
6	F	52	22	none	South	E	56	48	1-3,12		Low center	
7	J	18	22	none	SE flow	J	41	48	1-3,12		SW flow	
8	D	73	21	none	Calm wind	G	32	47	1-3,12		SE flow	
9	E	78	21	none	South	A	159	46	1-3,5,12		NE flow	
10	B	151	20	1	North flow	C	67	44	1-5,12		North flow	
11	G	40	18	1	NW flow	L	24	40	1-5		High center	
12	H	35	17	1	High center	I	23	32	1-10		West flow	

Table 15. (Continued)

Rank	Type	Summer				Fall				
		N	Conc	Sig	Remarks	Type*	N	Conc	Sig	Remarks
1	L	8	122	2-13	High center	L	19	79	4,6-14	South flow
2	F	44	89	1,11-13	SE flow	E	53	73	4,6-14	High center
3	H	35	86	1,11-13	High center	D	48	60	7,9-14	WNW flow
4	B	126	82	1,11-13	High center	A	197	57	1,2,7,9-14	SE flow
5	A	181	81	1,11-13	South flow	K	20	57	10-14	SE flow
6	E	46	81	1,12-13	SW flow	M	16	50	1-2,12-14	South flow
7	C	79	80	1,12-13	SE flow	B	114	45	1-4,12-14	South flow
8	M	78	79	1,12-13	SE flow	I	50	45	1-2,12-14	Low center
9	I	9	74	1,12-13	South flow	J	20	38	1-4	High center
10	J	10	73	none	South flow	F	37	34	1-5	High center
11	G	56	70	1-5	North flow	N	13	32	1-5	Low center
12	D	50	61	1-9	NW flow	G	72	28	1-8	Low center
13	K	18	61	1-9	High center	H	76	28	1-8	NE flow
14						C	58	27	1-8	High center

N = number of station observations

Conc = concentration in $\mu\text{g}/\text{m}^3$

Sig = indicates a significant difference between the ranked types listed and the ranked type of concern

*Type I (no data)

summer map types. Map type E(850S) has an easterly flow due to a high to the NNE, and map type A(850S) has a WSW flow into St. Louis. For the geostrophic wind, (Table 10) summer map types B, G, C and A have significantly higher O₃ concentrations of 83, 82, 82, and 81 ppb, respectively, when compared to the other types. The flows for these map types are from the south, except for map type G, which has light and variable winds due to the presence of a high pressure system centered over the area. Surface level map type L has the highest statistically significant concentration (122 ppb) for eight observations, but then there were no significant differences for map types ranked two through ten with O₃ concentrations ranging from 89 to 73 ppb. Map type L correlates with the highest concentration but the small number of station observations makes it of questionable usefulness. Other than this one type, L, there are more map types associated with the moderate to high O₃ concentrations and fewer unique synoptic pattern characteristics for the surface level.

The results from the comparison of the three sets of map types for the rest of the year for O₃, CO, and TSP concentrations are similar to the results during the summer. Table 16 gives the map types associated with the maximum and minimum O₃, CO, and TSP concentrations for the 850 mb, geostrophic, and surface map types, the number of station observations, the mean concentration, and the significance for each season. The number of map types associated with either the maximum or minimum mean pollutant concentration for the three sets of map types are indicated by the significance column. For example, to determine the number of map types associated with maximum springtime O₃ concentrations for the 850 mb, geostrophic, and surface patterns, an analysis of the significance must be accomplished. For the 850 mb level, spring map type E is associated with the maximum O₃ concentration, and it is significantly different from the remaining five 850 mb map types for the spring season. Surface spring map type M is also correlated with the highest O₃ concentration; however, it is significantly different only from map types 6-12 (the surface level identified 12 to 14 map types per season), and it is statistically similar to the four map types 2-5. Therefore, all of the first five map types are associated with higher pollutant concentrations. Similarly, the first two geostrophic map types are associated with higher O₃ concentrations. Thus the 850 mb pattern seems to provide a better classification of the high O₃ days.

An inspection of Table 16 shows that the 850 mb, geostrophic wind, and the surface map types all correlate with pollutant concentrations; however, the 850 mb map types appear to stratify the pollutants into a more limited number of types than the other two procedures. This is related primarily to the fact that there were fewer map types identified for the 850 mb analysis and thus larger pollutant case populations could relate to each type. The greater number of surface and geostrophic map types implies that two or more of these map types are represented by one 850 mb map type. This is indicated in Figure 15, which shows the frequency distribution for the surface and geostrophic map types in relation to map types E(850S) and D(850S). The frequency indicates the number of days that are common to the surface or geostrophic map type and to map types D and E for the 850 mb level. Map types D and E were chosen because they repeatedly identify with high pollutant concentrations for the summer. The data in Figure 15 show that each of the 850 mb map types correspond to several surface or geostrophic map types.

Table 16. Comparison of seasonal 850 mb, geostrophic, and surface map types in relation to maximum and minimum O₃, CO, and TSP seasonal concentrations.

Maximum Concentrations	850 mb				Surface				Geostrophic			
	Type	N	Conc	Sig	Type	N	Conc	Sig	Type	N	Conc	Sig
O ₃ - winter spring summer fall	D	170	22	none	K	27	29	10-12	I	38	34	2-9
	E	43	71	2-6	M	11	68	6-12	H	37	53	3-9
	E	57	88	3-6	L	8	122	2-13	B	82	83	3,9
	F	27	75	2-6	L	19	79	4,6-14	G	43	75	4-9
CO - winter spring summer fall	C	79	2810	2,3	N	8	1081	9,11-14	H	30	1933	8,9
	E	45	669	6	I	14	2260	2-12	F	42	848	2-9
	E	66	885	2,4-6	M	7	768	12,13	G	37	805	7-9
	F	28	2071	2-6	H	29	572	G 43		75	4-9	
TSP - winter spring summer fall	C	79	2810	2,3	N	8	1081	9,11-14	H	30	1933	8,9
	E	45	669	6	I	14	2260	2-12	F	42	848	2-9
	E	66	885	2,4-6	M	7	768	12,13	G	37	805	7-9
	F	28	2071	2-6	H	29	572					

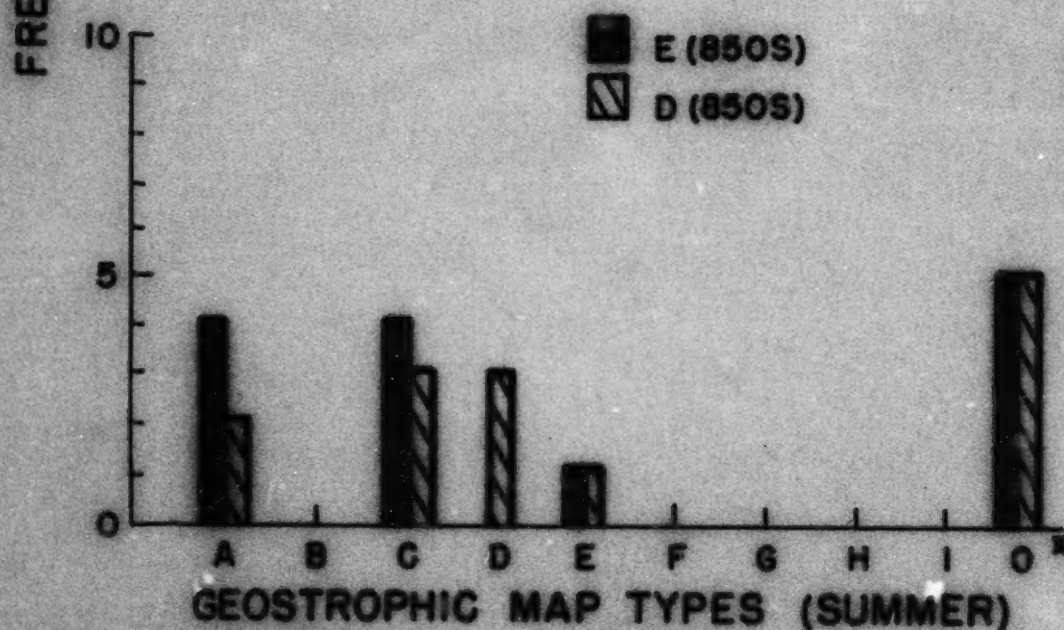
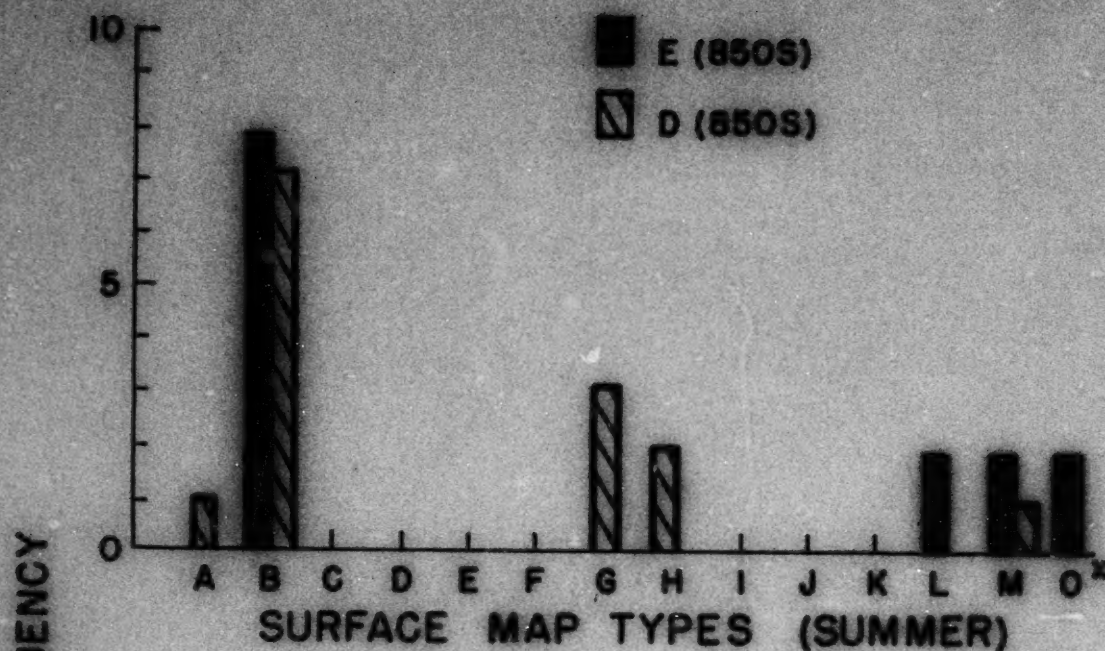
Table 16. Continued

Minimum Concentrations	850 mb			Surface			Geostrophic					
	Type	N	Conc	Sig	Type	N	Conc	Sig	Type	N	Conc	Sig
O ₃ - winter spring summer fall	A	317	20	none	H	35	17	1	H	38	12	1-7
	C	196	47	1,2	I	23	32	1-10	F	49	37	1-5
	F	39	55	1-5	K	18	61	1-9	D	63	69	1-4
	D	26	24	1-5	C	58	27	1-8	B	160	34	1-5
CO - winter spring summer fall	B	189	1149	1,2	I	35	300	1-7,9,11	E	54	1005	1-3
	D	34	475	1	K	19	705	1	E	49	458	1-3
	F	42	555	1,2	G	20	309	1	F	57	585	1-3
	D	26	684	1	I	7	213	1,2,4	B	168	740	1-3
TSP - winter spring summer fall	C	8	92	none	G	12	62	2-4	C	32	81	2
	C	62	98	1,2	L	4	47	2,3	F	9	95	1
	D	20	110	2	I	8	41	1-9	H	24	101	1-5
	D	7	34	1-3	L	5	52	1-4	E	8	83	1-4

N = number of station observations

Conc = concentration, in ppb for O_3 and CO , in $\mu g/m^3$ for TSP

Sig. = indicates a significant difference between the tabulated type and the types identified under "Sig."



^xType O indicates dates not typed

Figure 15. Frequency distribution for surface and geostrophic map types relating to map types D(850S) and L(850S).

The occurrences of the 850 mb map type E are divided among three different surface and three geostrophic map types while cases of 850 mb map type D are related to five surface and four geostrophic types. Untyped maps, indicated as 0 in Figure 15 are not counted. These data also indicate that two surface and three geostrophic map types contain days from both of the 850 mb map types. This is evident with surface map types B and M, and geostrophic map types A, B and E.

The greater number of map types for the surface and geostrophic classes leads to a greater probability that overall two or more of the weather patterns have some similar features and lead to types that may not describe significantly different flow patterns. This dilutes the results of the air quality application and makes stratifying pollutants into distinct pattern types more difficult. The increased number of surface pressure patterns is due to the increased complexity of the surface regime of which the effects of friction and terrain are probably most important. The movement of air masses and the presence of frontal systems also affect the wind flow at the surface more than at the 850 mb level. A reduction in the magnitude of these factors leads to more generalized wind flows at the 850 mb level compared to that at the surface. For the geostrophic or pressure gradient types the poorer correlations with pollutants is attributed to difficulties in typing the geostrophic wind by components. As previously indicated, the geostrophic map types are based on pressure difference between certain station combinations with the assumption that the pressure gradient is uniform between the two stations, and the single indicated component of the geostrophic wind is a good indicator of the flow. For the best results, the maximum number of station combinations with a minimum distance between stations should be utilized along with sectors meeting at a large angle or even intersecting. Our choice of the number of station pairs and their distribution over the area was a compromise between the detail needed to describe the geostrophic system and the realities of the typing computation problem. Also, it is recognized that when the geostrophic wind is less than about 5 knots the wind regime will probably be dominated by the local wind systems rather by the apparent geostrophic pattern (Moses and Hess, 1976).

SECTION 3

SUMMARY AND CONCLUSIONS

The statistical map classification procedure developed by Lund (1963) served as the basis for compiling comprehensive sets of primary seasonal weather map types for the 850 mb level and for components of the geostrophic wind using surface pressure differences between paired stations for the four year period 1973-1976, for the St. Louis, Missouri, region. These map types were matched with mean concentrations of ozone, carbon monoxide, total suspended particles, sulfate and nitrate data applicable to the St. Louis central urban area, using observations from the St. Louis RAMS network for the period 1975 and 1976 within the larger St. Louis RAPS program.

The average pollutant data, stratified by weather type, were assessed by analysis of variance statistical techniques using the Duncan's multiple range test (Steel and Toerie, 1960). This was a basis for determining significant differences between map types within each season of the year. The results indicated that the regional synoptic scale patterns for the 850 mb, surface, and geostrophic wind components can be used to classify the pollutant concentrations for all of the pollutants considered. Higher pollutant concentrations repeatedly occurred with wind flows from the south and/or the presence of a high pressure system in the area while lower concentrations occurred with the presence of a low pressure system and/or strong wind fields. Maximum mean pollutant concentrations were found to differ by season, depending on the type of pollutant. For example, higher ozone concentrations occur during the summer months due to more favorable conditions for the photochemical reaction processes. Lower ozone concentrations occur during the winter season.

The 850 mb and the geostrophic map types were compared to the surface map types developed by Robinson and Boyle (1980). The 850 mb map types were concluded to be the most effective in stratifying the pollutant data. This conclusion was a result of the lower number of seasonal map types and thus the better resolution of major patterns by the 850 mb types than for the surface or geostrophic map types.

The results of this investigation comparing different weather pattern types with air quality should provide a basis for future research relating air quality to synoptic flow. This study provides a basis for the use of 850 mb flow level map types with diffusion models for the prediction of pollutant concentrations at receptors located long distances from a major source. The results might also aid in the prediction of periods of high or low pollutant concentrations, in an effort to curtail harmful pollutant episodes. For

research programs where it is useful to deal with similar synoptic situations either at 850 mb or at the surface the results of this study, as tabulated in Appendix A-1 for 850 mb types, or Table 3 in Robinson and Boyle (1980) for surface pattern types could be used to select similar synoptic patterns. The base maps for each identified type are given in the appendices of the final report for each study.

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APPENDIX A

DAILY MAP TYPE ASSIGNMENTS

As a result of this program map types were assigned to each day for the 4-year period 1973-1976. A tabulation of these daily map types is given in Table A-1 for the 850 mb contour patterns and in Table A-2 for the geostrophic patterns. In these 2 tables the identifications is by letter code in each season. The notation 0 indicates that the map was not typed within one of the map categories, i.e. no correlation met the typing qualification. The notation X indicates that some data were missing and thus no type was assigned to the daily pattern. These tables can be compared with a similar tabulation of surface patterns given by Robinson and Boyle (1980) in their Table 3.

Table A-1. Daily 850 mb map type assignments, 1973-1976.

Year	1973					1974				
	Month	Winter D J F	Spring M A M	Summer J J A	Fall S O N	Winter D J F	Spring M A M	Summer J J A	Fall S O N	
DAY	1	A A C	A F B	A A B	C X X	X B A	C B C	O B A	X B C	
2	C A C	B X B	B C A	X A B	C X X	X A A	A A B	O X F	O B C	
3	C C B	B C A	B C A	C A B	X X X	B A B	A A B	A A F	O F C	
4	C A A	A O C	A O C	A B X	X X X	B A B	A F C	A A F	E A A	
5	X A A	O C C	B A X	F A C	X X X	A A C	A C C	C B B	O C D	
6	A A A	B B B	B B F	B C C	X X X	C A C	A A C	C A O	C A B	
7	B B A	A D F	A D F	F A A	X X X	C X B	A F B	C C C	O B B	
8	O B B	O O C	O O C	F A A	X X X	B A B	X F B	C C C	O B C	
9	B B B	B F X	B F X	A A A	X X X	A C B	A E A	X C C	O B C	
10	X A O	B C C	B C C	A O A	X X X	A A B	A E A	A A O	C A B	
11	A B C	A A C	A A C	A O A	X X X	A A A	X B B	B A O	C A A	
12	A A C	A A C	A A C	F A B	X X X	A A A	F B O	A O A	A A B	
13	B A C	B A C	B A C	X A F	X X X	A A A	D A X	A A O	A A B	
14	B A B	A B C	A B C	C B B	X X X	A A A	O B B	A A O	B A B	
15	B A B	A B C	A B C	C B B	X X X	A A A	O B B	A A O	B A B	
16	O X B	D A C	D A C	A O C	X X X	C A A	A C B	F B C	B B A	
17	O C A	C B C	C B C	A X C	X X X	A A A	C C B	B O F	B B A	
18	C A A	C B A	C B A	C C O	X X X	A C A	C A B	A A A	X B A	
19	X A A	O B C	O B C	A A B	X X X	A A X	C A B	A A B	A B A	
20	R C A	D B B	D B B	F A B	X X X	A A C	C B B	A B C	A B A	
21	A O B	D A B	D A B	B O D	X X X	A A C	A B B	X O C	B F B	
22	C A B	B A A	B A A	B C C	X X X	A A B	C A C	A O C	B A F	
23	C B A	O O O	O O O	A C C	X X X	A A A	A C C	O B F	B A A	
24	C B A	O O B	O O B	A C C	X X X	A A A	A O O	O B F	B A A	
25	C B A	O O B	O O B	A C C	X X X	A A A	A O O	O B F	B A A	
26	A O A	D D B	D D B	A F A	X X X	A A B	A A D	D C C	C A B	
27	O O B	B C F	B C F	A B C	X X X	A A A	A B A	D F C	A B B	
28	A A B	B A C	B A C	B B C	X X X	A A A	A A A	D B A	A C B	
29	A A	O B C	O B C	B B C	X X X	A A A	A A A	D B A	A C B	
30	A A	O B C	O B C	B B C	X X X	A A A	A A A	O B A	O C C	
31	O A	O	O	F	X	A A	C	A	C	

Table A-1. (Continued)

Year	Month	1975				1976			
		Winter D J F	Spring M A M	Summer J J A	Fall S O N	Winter D J F	Spring M A M	Summer J J A	Fall S O N
DAY	1	A A A	C A A	B E E	A A A	A O A	A C O	F B B	O B X
	2	A B A	C B A	F E O	B B A	A X B	B C C	O A O	O E X
	3	A C O	C F B	A O F	A B A	A A A	B A C	D A D	C E X
	4	A A C	C X C	A B F	B A A	A B A	A C C	E O O	A C X
	5	A A C	A X A	A B O	A C O	A A A	B C A	E D A	B C X
	6	A C B	A X B	B A O	B A C	C A A	A C A	E D A	F D X
	7	B A B	B X B	B B X	B C C	B A B	A C E	D O O	C O X
	8	A C A	C X O	C X C	B C A	B B A	A E C	X B O	C O X
	9	B A A	C X D	O X A	C A O	A B B	O D C	A A C	O O X
	10	B C A	B X C	O X A	A A X	A A A	C A C	A A A	B B X
	11	A X A	A X C	O X A	A A A	A A A	B O C	A B A	B A X
	12	A A A	B X C	F B A	B A B	A A A	X A A	A B A	A C X
	13	C B A	A X C	A O A	B C E	A B B	A A O	C A A	C B X
	14	C B A	O X B	A A A	C A B	A A C	A B O	A A A	O A X
	15	A A C	C X O	F C A	A B A	B A A	O B O	F B A	O B X
	16	A A A	B X O	C C A	C O A	B B A	C B C	A B O	E B X
	17	X A A	B X A	A C A	C E C	A B C	A A C	C B D	F C X
	18	B A A	O A A	C A A	A B C	A A A	B B A	F A E	A D X
	19	A B A	C X A	C A A	B A D	A X C	A A E	B A C	B B X
	20	B X C	B C B	C B A	B C B	B B B	C A E	O A C	B A X
	21	O A C	A B B	C A C	B C A	A A B	A F D	C B E	A A X
	22	B A O	B A B	C A A	O E A	A A A	B D E	A A C	A D X
	23	O A O	A A B	C B A	E X O	B O A	A E O	A A A	C E X
	24	C A B	C E B	C B A	F C O	B B A	A E O	A A A	O B X
	25	O X B	B B C	C B A	A A C	A A A	B O B	A A A	B A C
	26	B A A	B B E	O B C	C A B	B A A	A	B A O	B C E
	27	A A A	A A X	E E A	A B C	A A A	A		
	28	C C C	A	C O	C	B B			
	29	A A A							
	30	A A A							
	31	A A A							

X - data missing, No type assigned

0 - misc. (not typed)

Table A-2. Daily geostrophic map type assignments, 1973-1976

Year		1973					1974						
Month	Day	Winter D J F	Spring M A M	Summer J J A	Fall S O N	Winter D J F	Spring M A M	Summer J J A	Fall S O N	Winter D J F	Spring M A M	Summer J J A	Fall S O N
1	1	A B O	A E D	A A D	A O I	B H O	A E O	O A O	G B A	B O B	A E O	O A O	G B A
2	2	A C I	O E E	A B D	C A B	B O B	D A O	O B O	B C O	E B B	O I O	O B F	B C O
3	3	A G O	O B C	B O O	A A O	C H A	O B O	A B O	B A F	C H A	O B O	A B O	B A F
4	4	O B O	F B C	B G A	O D B	G B A	D B E	A G O	D A O	A G I	D B E	A G O	D A O
5	5	D B O	C D A	O A A	O A C	A G I	F F C	A O O	C A B	G B I	D F F	A O O	C A B
6	6	B B B	A I A	O A A	C A E	I H B	A G H	B A E	C B D	B O O	A G H	B A E	C B D
7	7	C O I	H F O	A B B	I A B	A O O	F F C	E A E	D D C	A O O	A G C	E A E	D D C
8	8	O B B	F O O	F I F	G A B	O B I	O A A	B H E	O O C	O B I	O A A	B H E	O O C
9	9	B B H	A B O	A D B	O A A	A O I	O A H	F C B	A A C	O B A	O A H	F C B	A A C
10	10	E A B	E O O	H O O	B A A	A H A	G D O	O C O	A A B	A H A	G D O	O C O	A A B
11	11	G C A	C O B	O O O	I A A	O A O	C A A	B O I	H G F	A O O	C A A	B O I	H G F
12	12	E D G	A C B	O C F	O E I	A D C	E O A	B G C	A B E	A D C	E O A	B G C	A B E
13	13	O O I	D A B	E G I	G F B	B O B	B B D	G D A	D E A	O A O	B B D	G D A	D E A
14	14	B C B	O A H	A C A	O B C	O A A	C H F	O A O	O E A	B O B	C H F	O A O	O E A
15	15	E A E	B O O	O C A	B E A	O A F	B B F	B H O	O E A	O A F	B B F	B H O	O E A
16	16	O A C	B A O	O A A	D C H	O G G	O A C	H C A	D B A	O G G	O A C	H C A	D B A
17	17	G F C	F A C	B O F	O F I	G G E	G A C	E O B	O C B	G G E	G A C	E O B	O C B
18	18	I O G	C D A	O E D	I C A	O I A	O A A	H C A	O C B	O I A	O A A	H C A	O C B
19	19	A G E	A D O	G O C	O A H	A G O	H D O	E O B	D O A	A G O	H D O	E O B	D O A
20	20	A D O	A O O	O E A	O A I	O I E	B G O	O O G	O A A	O I E	B G O	O O G	O A A
21	21	G O O	A F O	H O E	I A I	G O C	O C G	D C I	D O H	G O C	O C G	D C I	D O H
22	22	A O O	O O O	C O E	A A C	I C B	O A O	D O A	E E C	I C B	O A O	D O A	E E C
23	23	D A O	G O A	B O B	A O I	C C A	C A A	O O B	O C C	C C A	C A A	O O B	O C C
24	24	O O H	A C E	O F A	I B B	C C A	A D D	O O O	A A F	C C A	A D D	O O O	A A F
25	25	D F B	E A O	F I A	O O A	C C E	O O F	C G G	O A O	C C E	O O F	C G G	O A O
26	26	O F H	A A O	E F A	G O F	B O A	G B A	O O B	O A O	B O A	G B A	O O B	O A O
27	27	D F B	A I	E G A		O B	A	E O					
28	28	B C											
29	29	O A											
30	30	B A											
31	31												

Table A-2. (Continued)

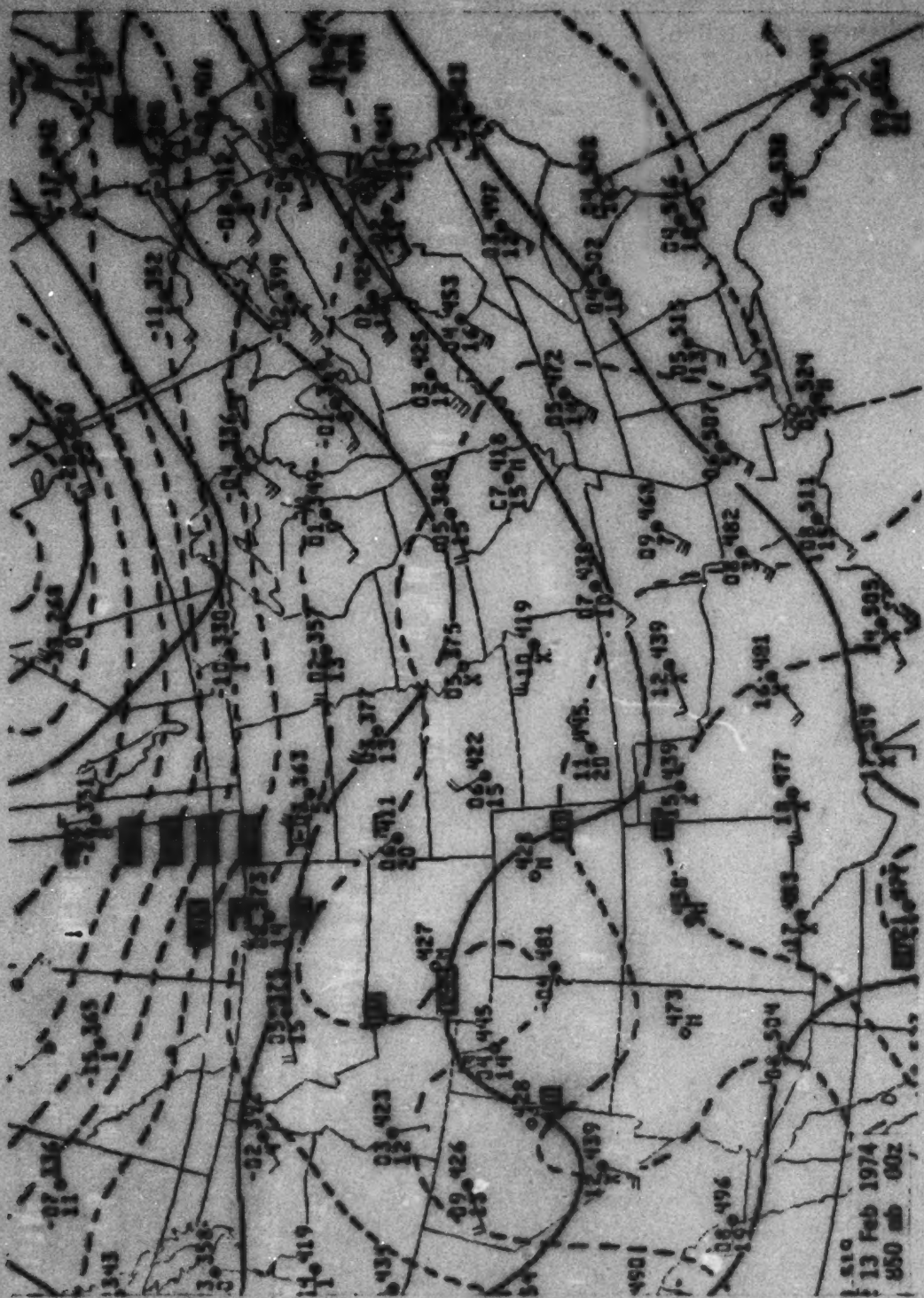
Year	1975					1976				
	Month	Winter D J F	Spring M A M	Summer J J A	Fall S O N	Winter D J F	Spring M A M	Summer J J A	Fall S O N	
DAY	1	A E O	B F O	O O O	O B A	O A B	A O O	I E D	G O A	A
2	2	O A H	B B A	A O F	O D E	H B D	I A E	C E O	C I F	F
3	3	A B H	B B E	A G O	O E A	F B D	O B H	O I A	C E A	B
4	4	A C O	O C C	B O O	O G C	H C O	I O D	C D A	O A B	A
5	5	F A B	D C C	F O I	F E A	A A B	B H I	C D E	C O A	A
6	6	O A B	F C C	O O C	D C A	I F B	H C O	O O D	D B B	F
7	7	O G D	B C C	I D C	O C A	O B D	O C B	O F O	A B D	A
8	8	O E O	G C F	E D A	C H O	C A A	O G H	O C C	O D A	F
9	9	E A C	A O G	O D A	A O E	A A I	O O H	A A A	B O F	
10	10	A O A	G B G	O D B	F C O	I A C	O O H	A O A	D C B	B
11	11	G O O	A B O	F O E	B A B	O E C	A O C	A O B	A A B	B
12	12	A B B	B C G	F D O	D A B	B A O	E O A	C C B	A H B	D
13	13	A O G	O A O	B O O	D H A	C B O	O A O	A O I	A B D	D
14	14	F A G	O O H	O A E	A B A	D O A	O D F	A O I	O E D	D
15	15	E O I	A C G	F A O	D B A	O F F	O D F	A F F	G B E	D
16	16	F O O	C A O	B A B	C B A	D B G	B A E	C D C	G B C	O
17	17	B A O	H D O	H B E	H O A	O H G	A D D	B O A	C I F	F
18	18	C O B	O O O	A F C	O A A	A D C	D C O	A A A	H B B	B
19	19	D B C	O E D	A O A	O A B	F O G	E F O	D H A	B B F	B
20	20	I A A	H C A	A O H	O A O	C B I	G E C	C E A	A A F	F
21	21	C C I	F A D	B A C	O A O	D A A	O F C	A A O	G I D	A
22	22	O C I	C A A	B B B	B E B	C O A	D A G	E A O	C B A	A
23	23	H A A	E F O	B H G	B C O	F O A	D O G	A A O	I B G	H
24	24	O D D	B C C	C O O	C A A	B I F	A B C	A A A	O B D	B
25	25	E O B	A A C	C O O	O A A	E C F	D C O	O E F	D E B	E
26	26	A G A	O O A	C C A	A O A	O D A	C O O	A A B	O O F	O
27	27	G A E	B D A	C A H	H A B	A O B	A O F	E F G	D E E	A
28	28	O B	O O B	C A I	A	B O	E O	G C C	O O	
29	29	H G	I	C O				D B G		
30	30									
31	31									

APPENDIX B

SECTION 1

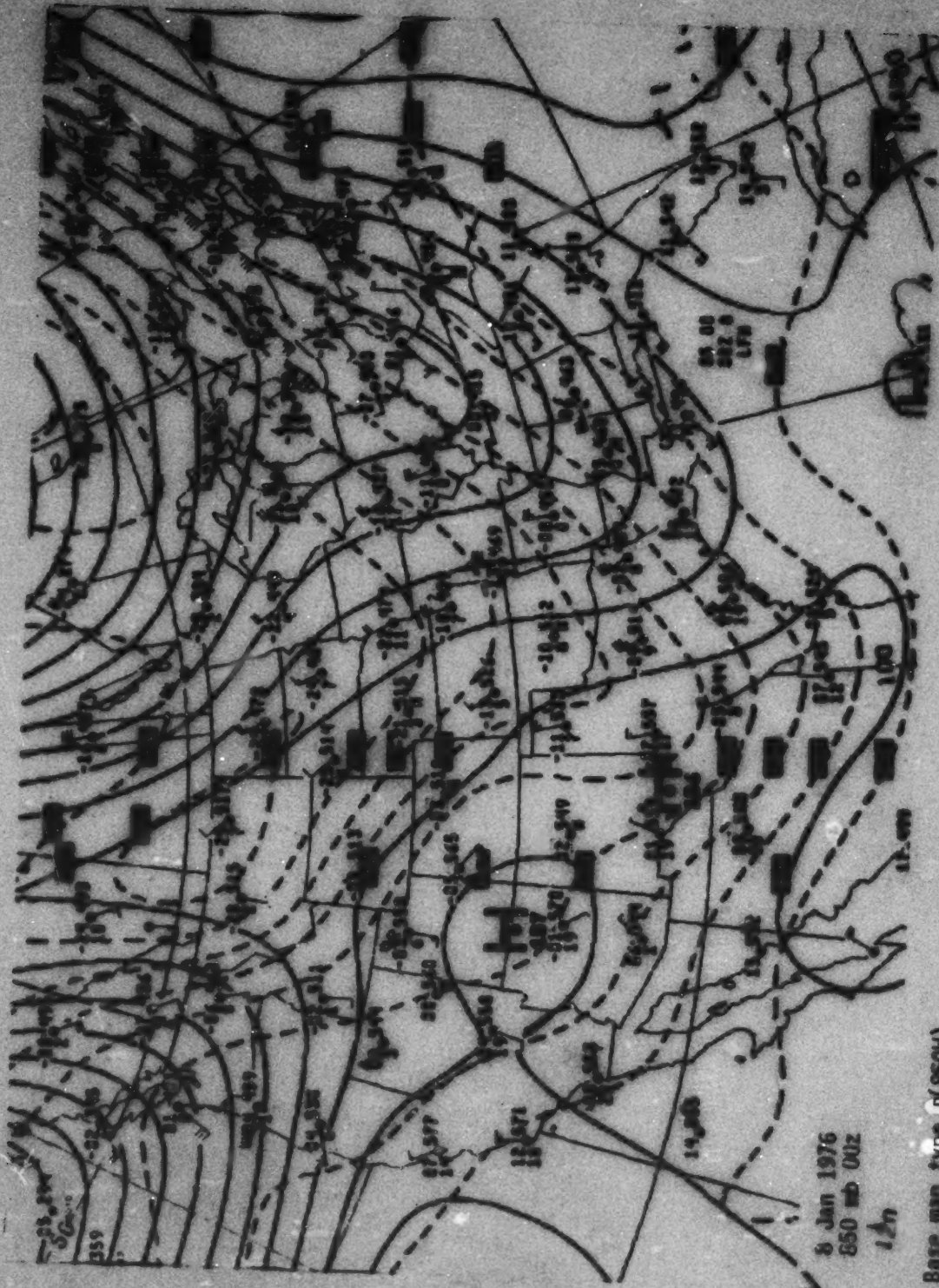
BASE MAPS FOR 850 MB





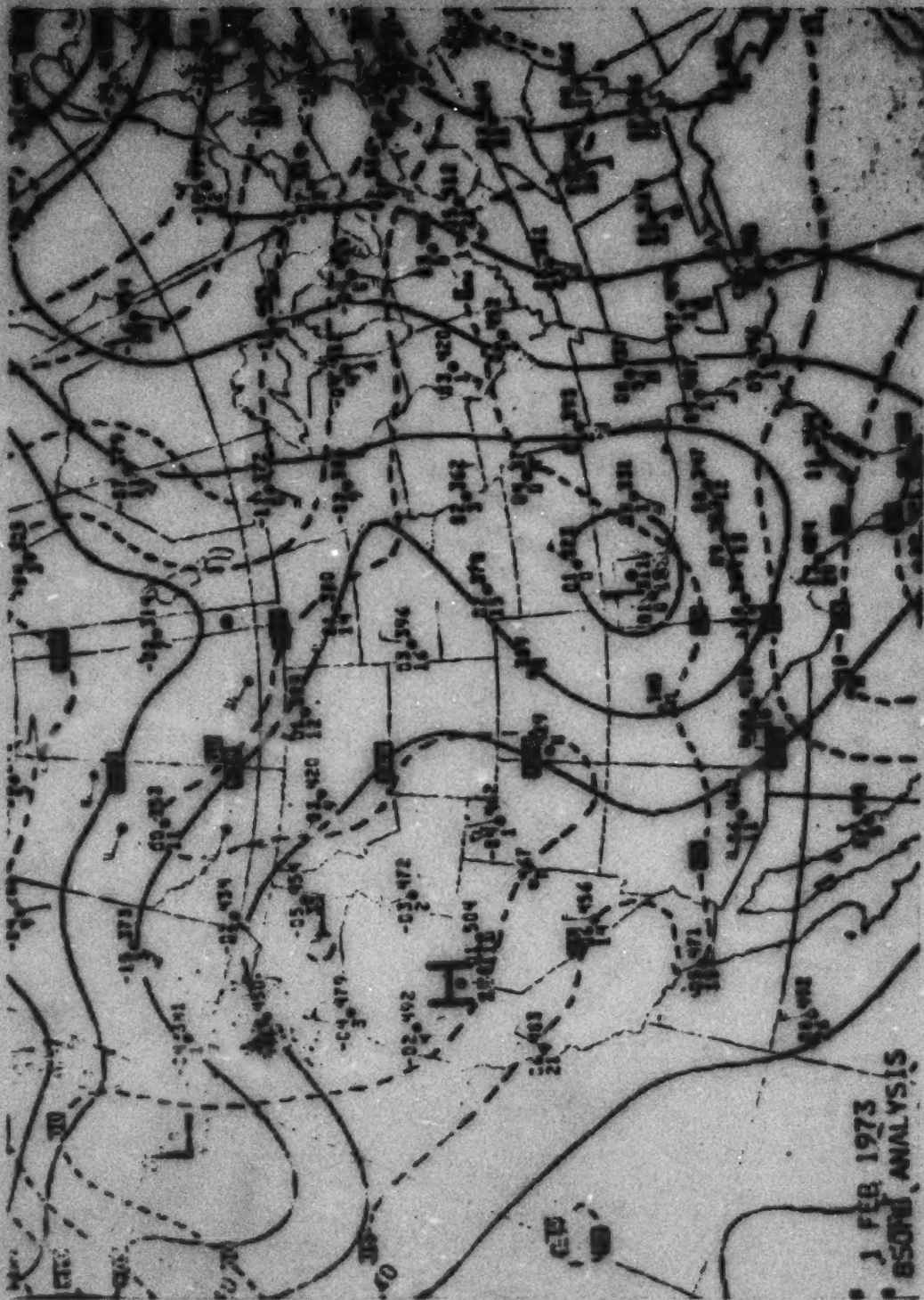
1. 510
13 Feb 1974
050 mb 00Z

Base map type A(050M)



5 Jan 1976
650 mb 01Z
1/1

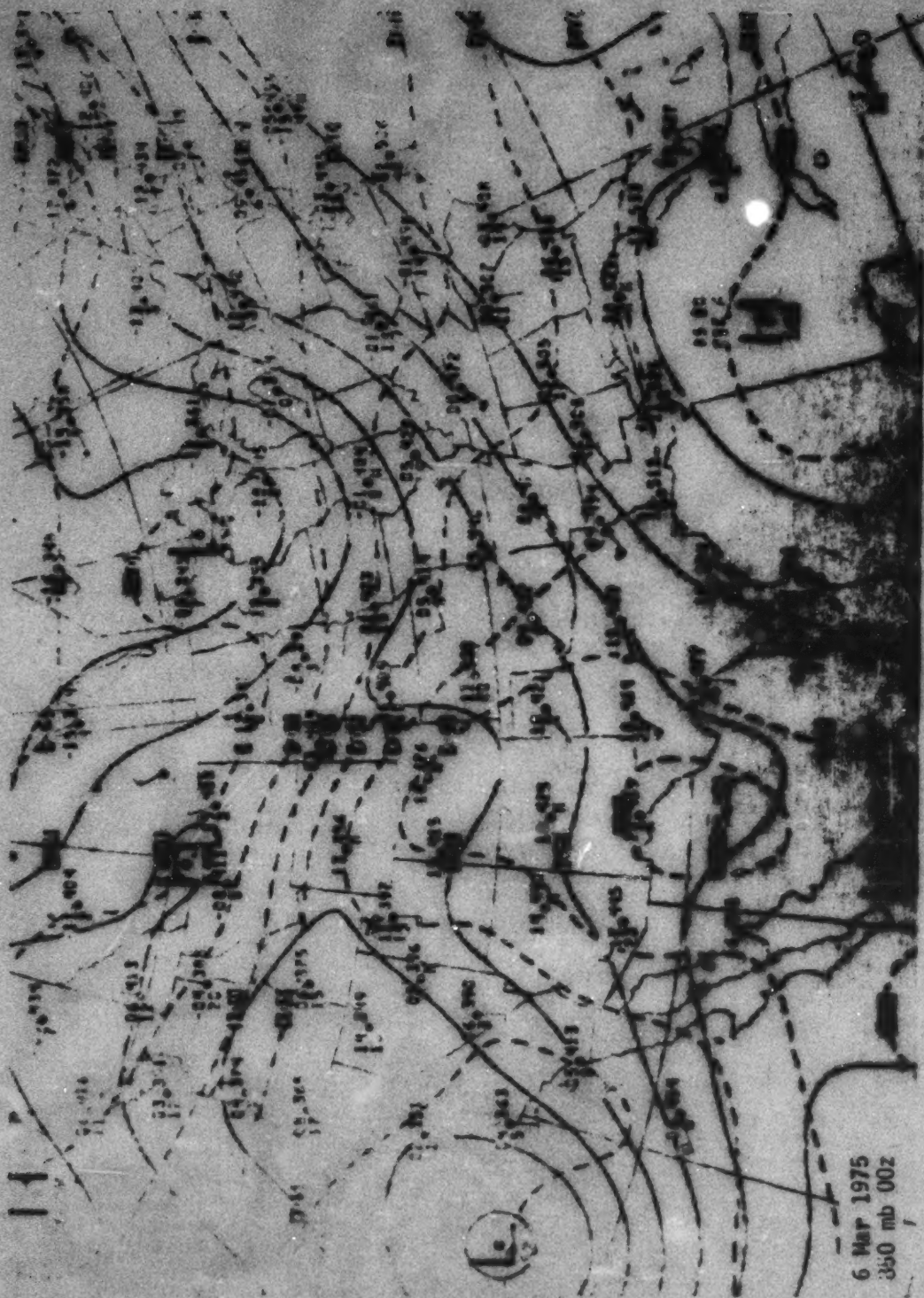
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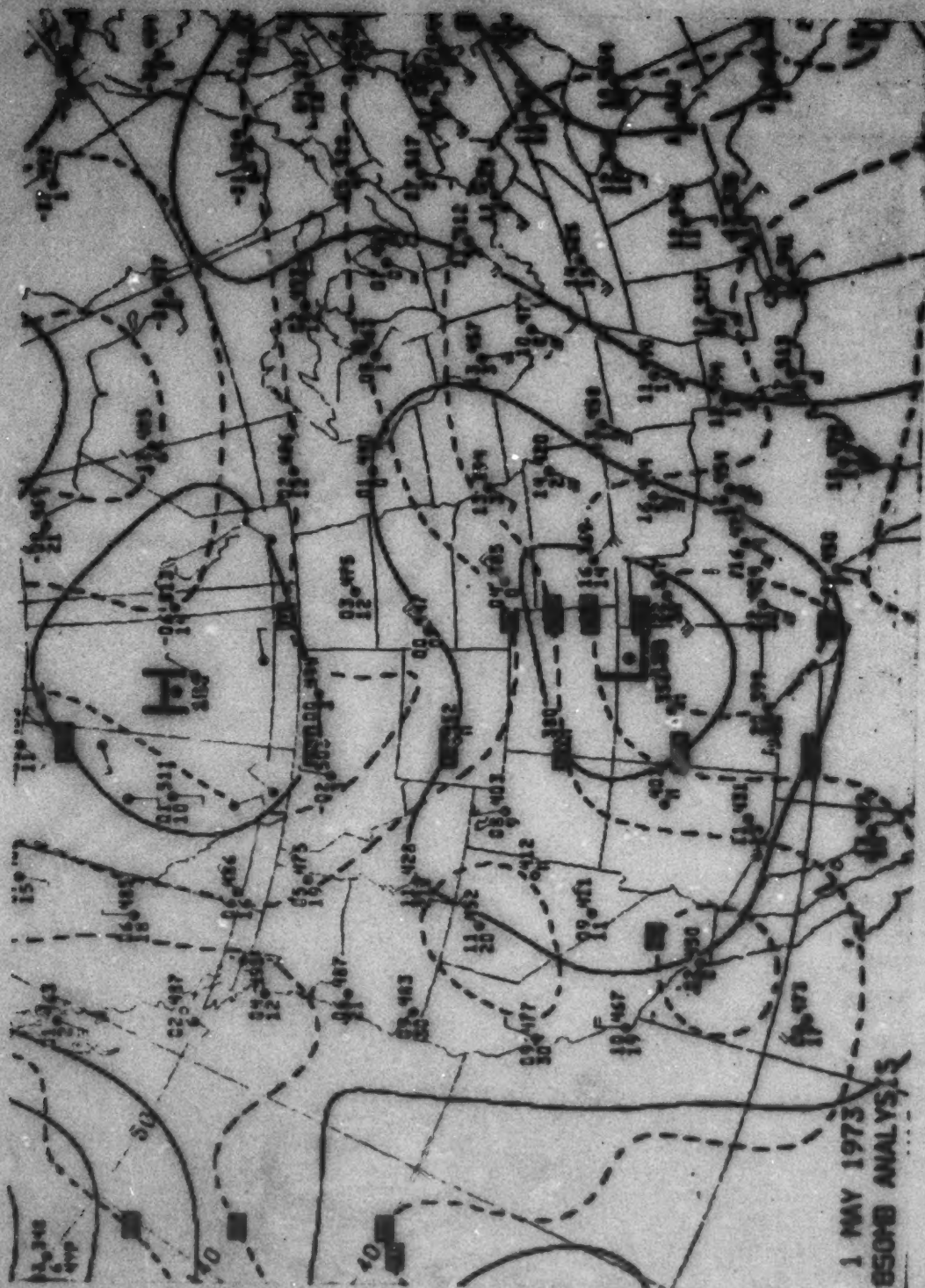
1 FEB 1973
850M ANALYSIS

Base map type C(850M)

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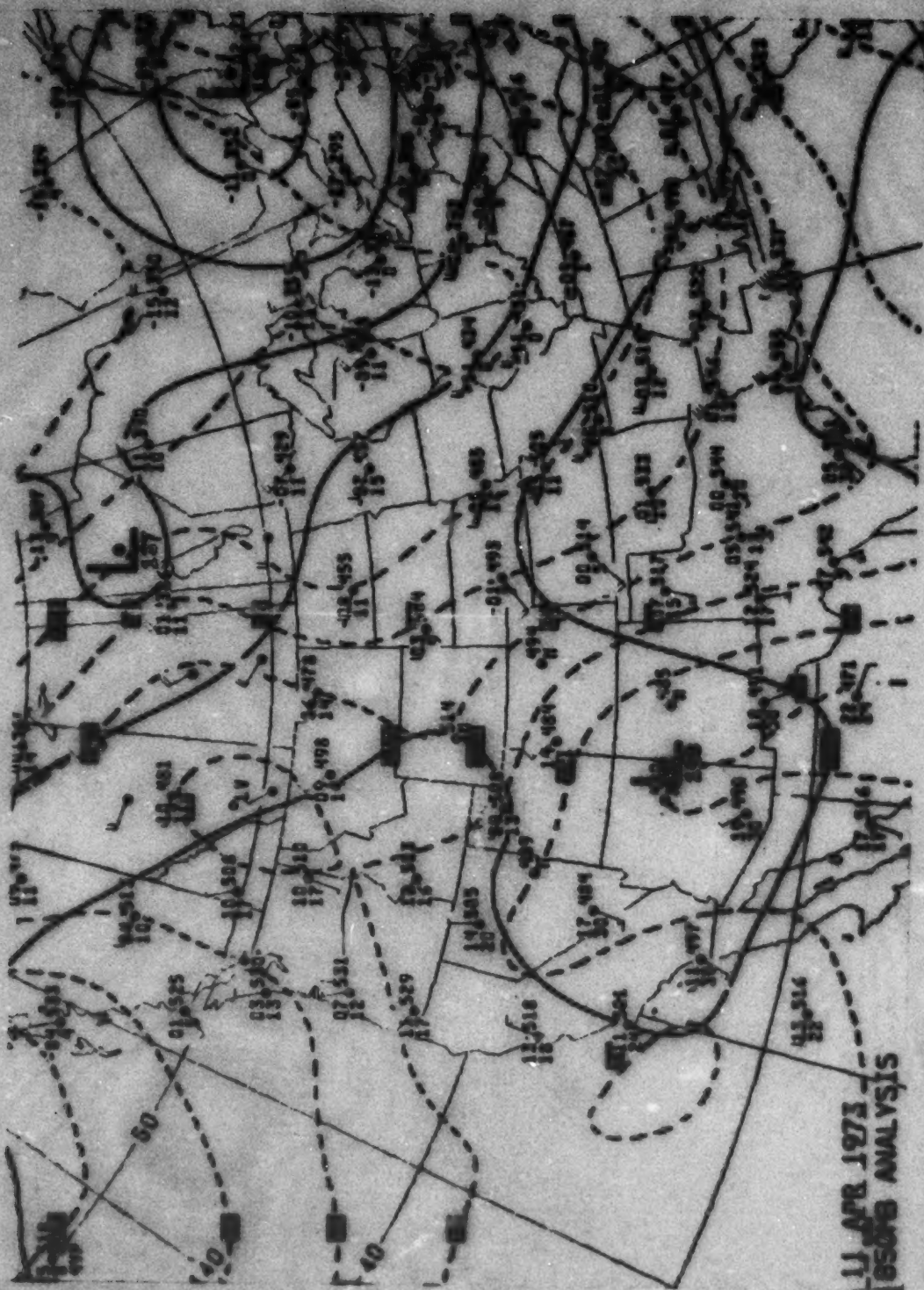


Reproduced from
best available copy.



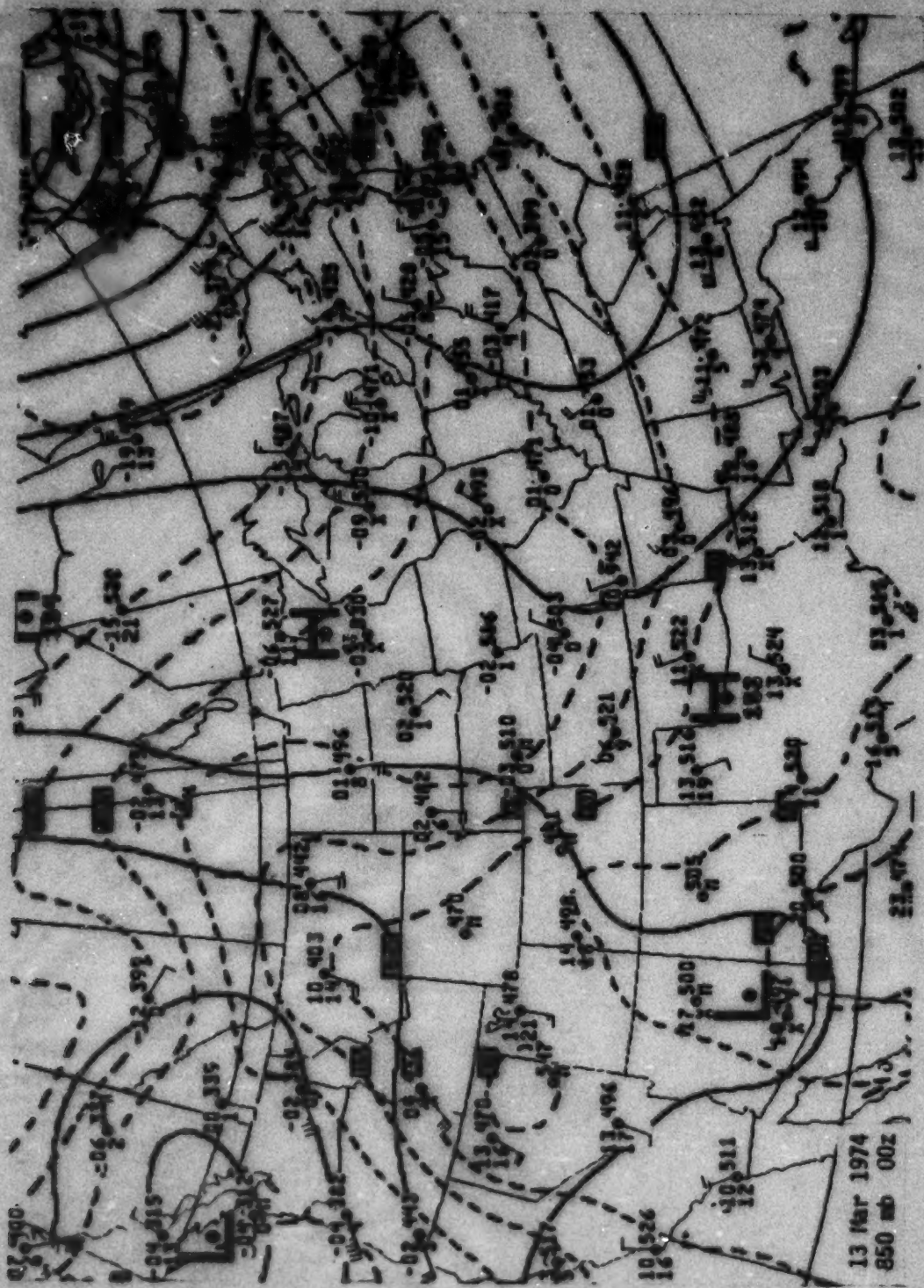
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850MB ANALYSIS

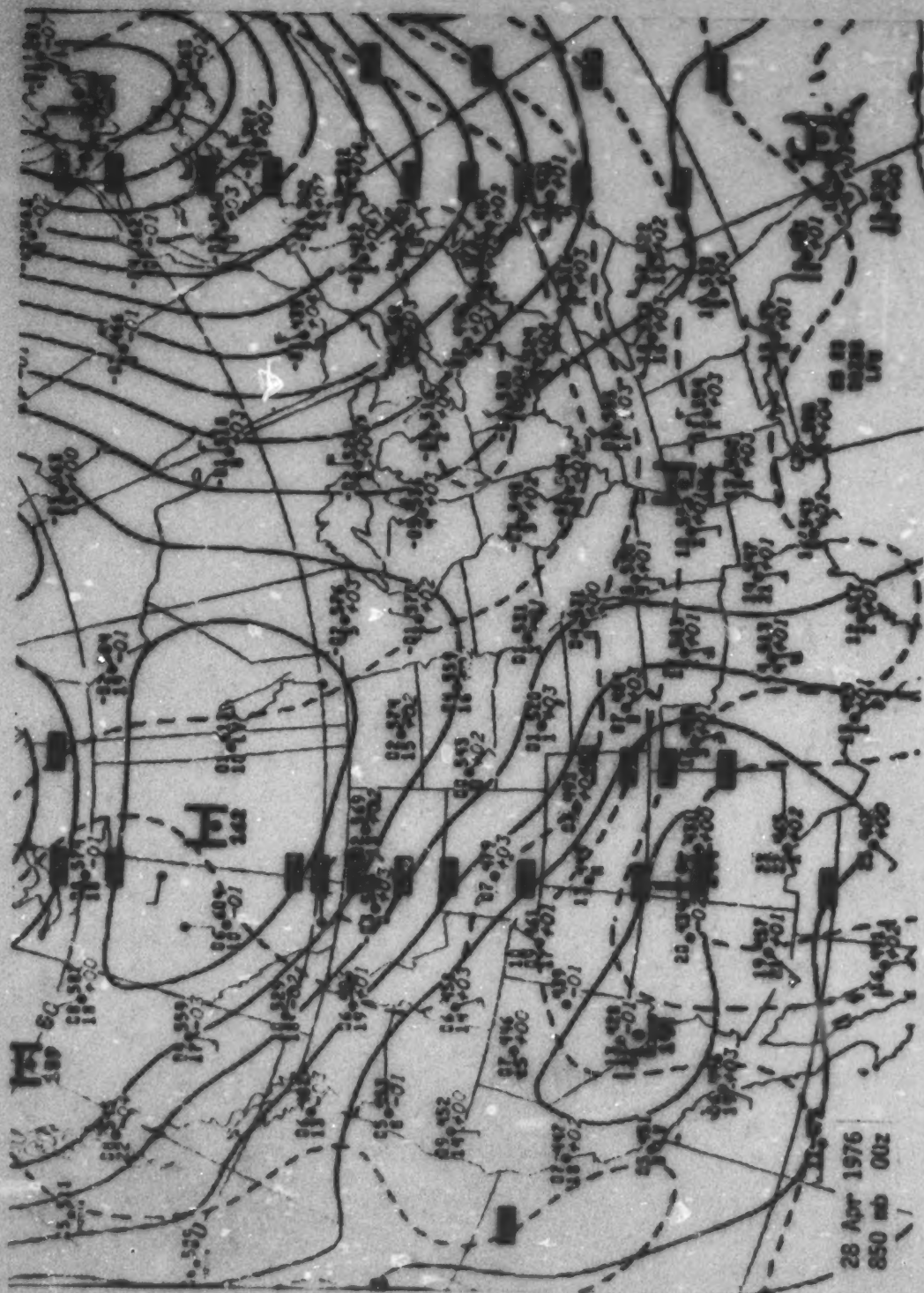
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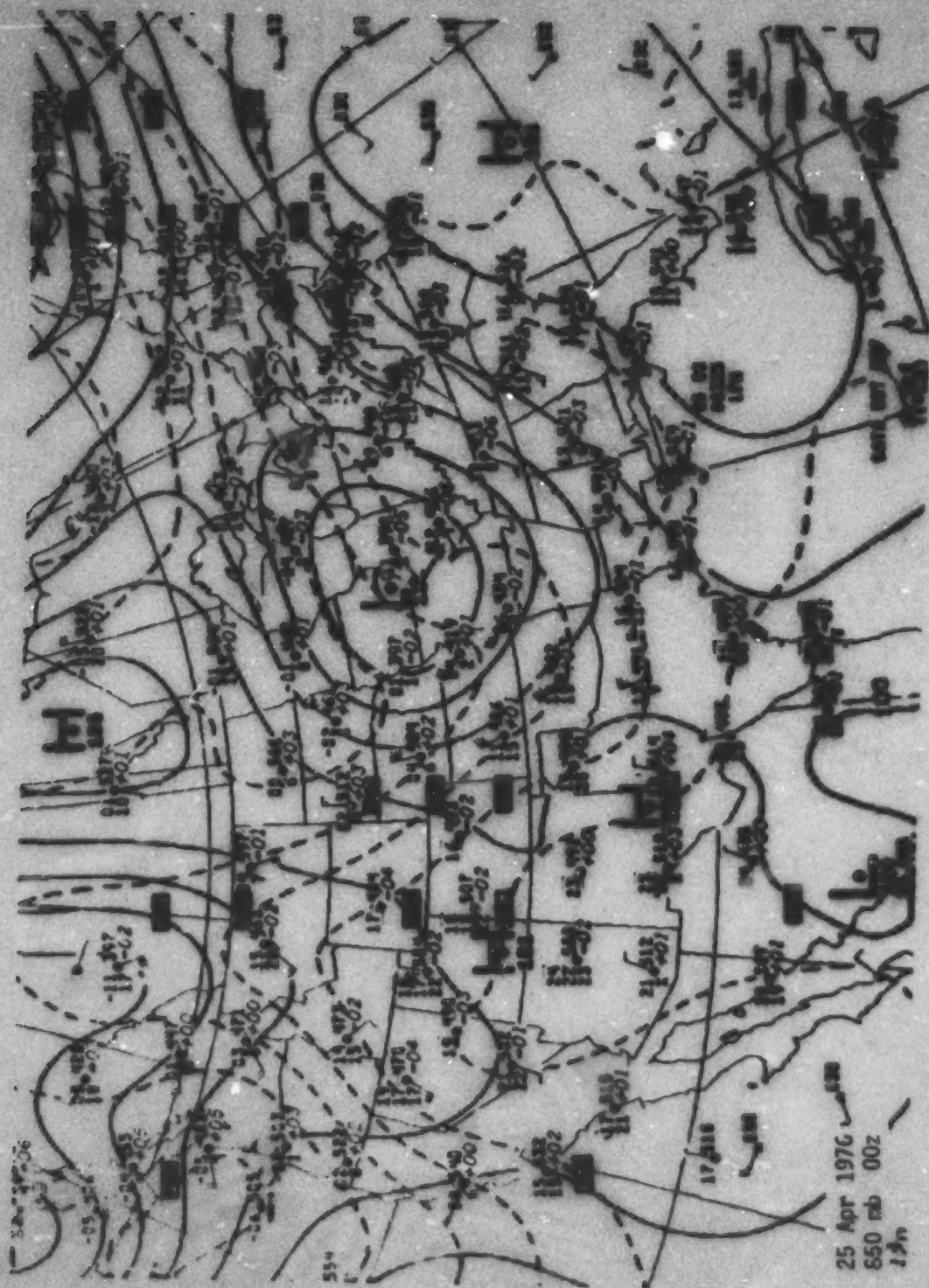
11 APR 1973
OSOB ANALYSIS

Base map type C(850SP)

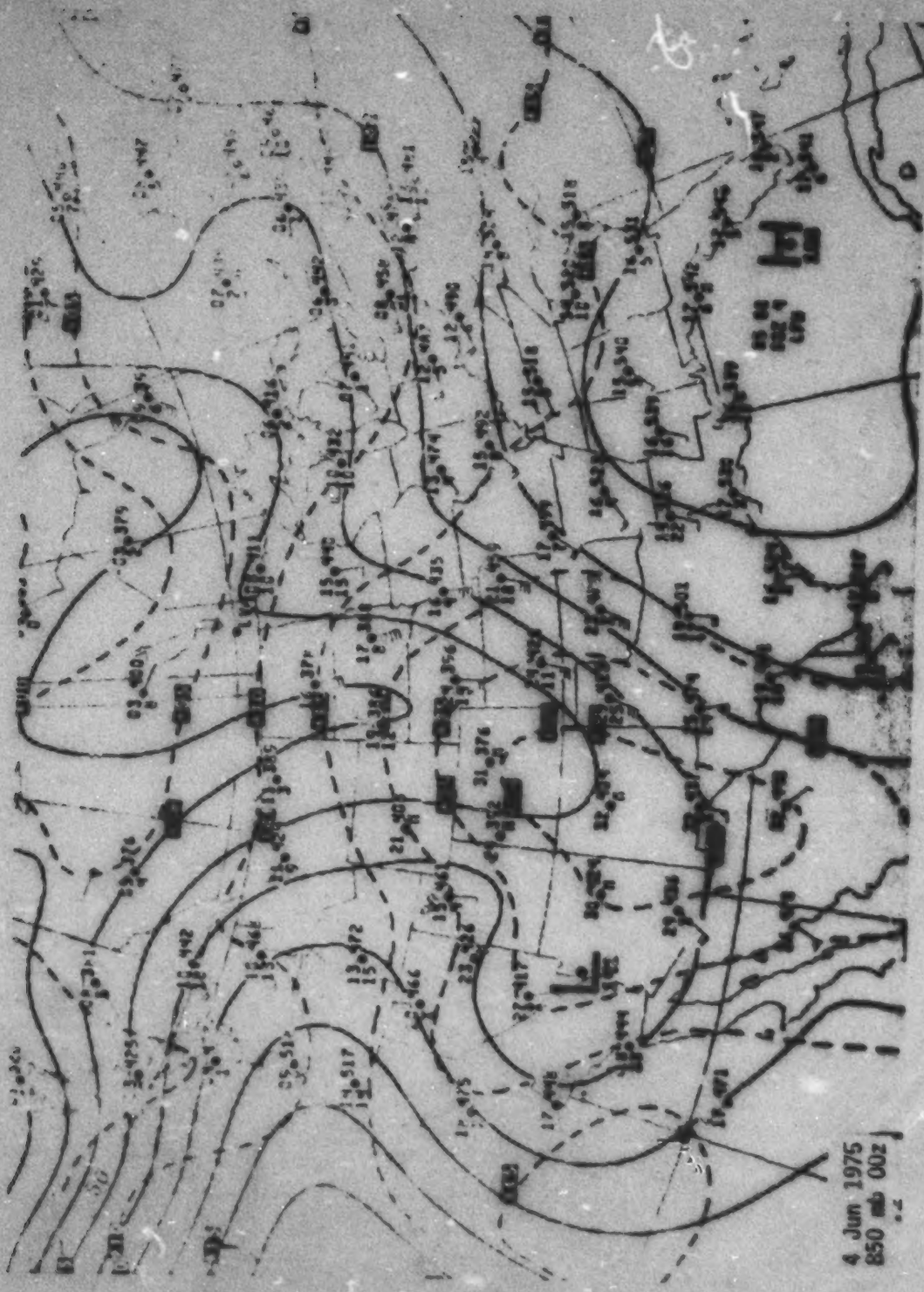




28 Apr 1976
850 mb 00z



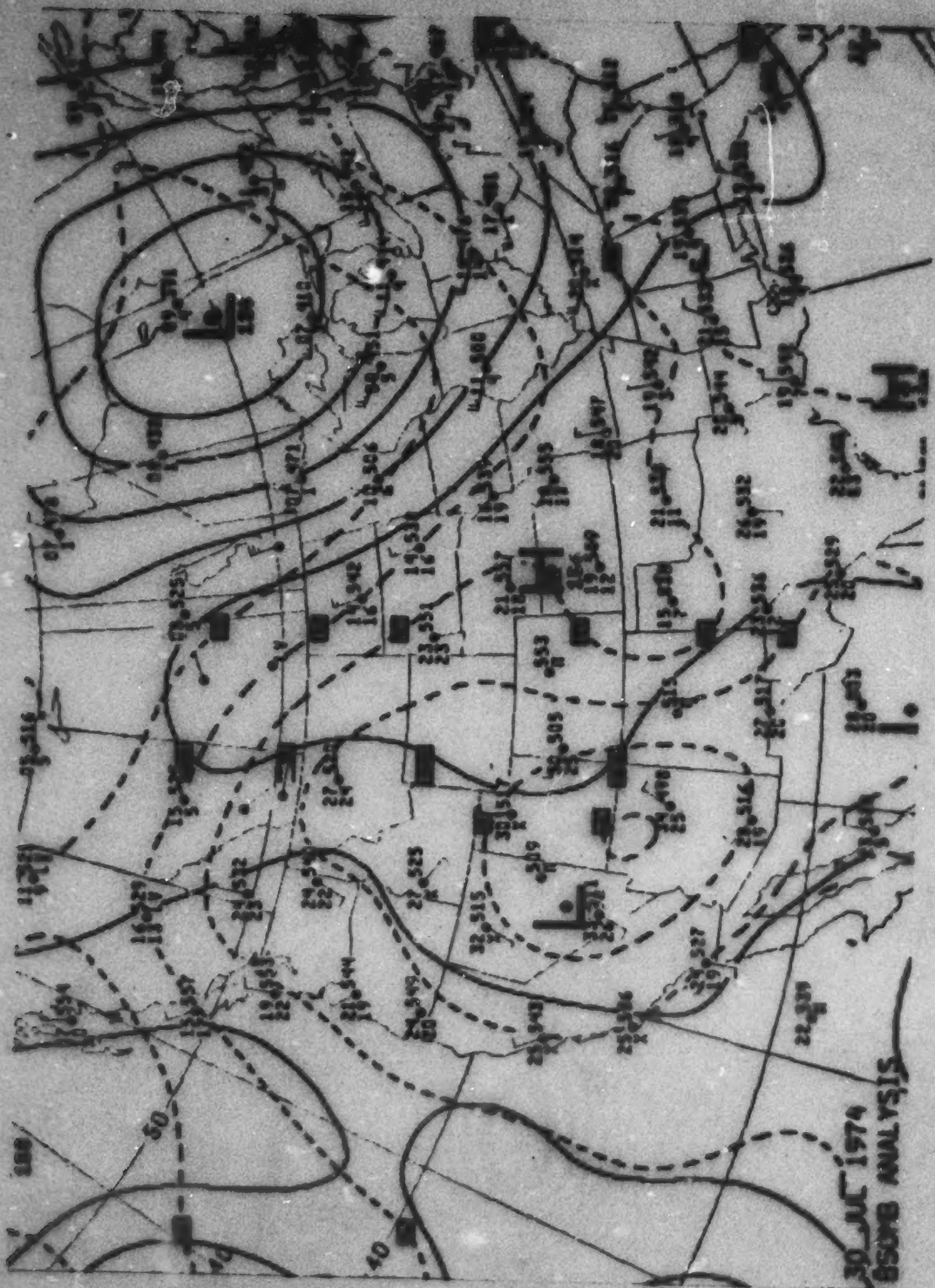
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4 Jun 1975
850 mb 002

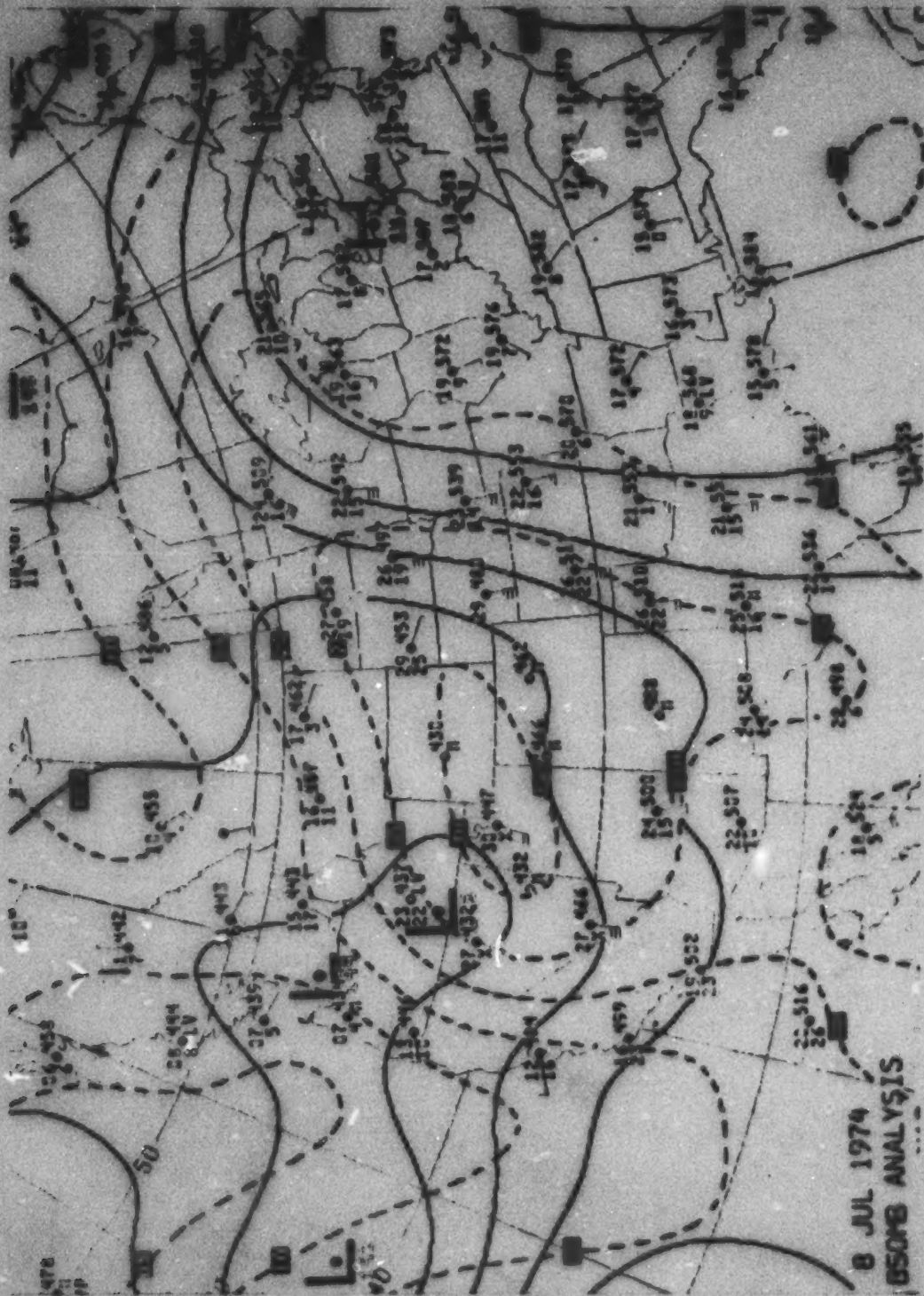
Base map type A (850S)

Reproduced from
best available copy.



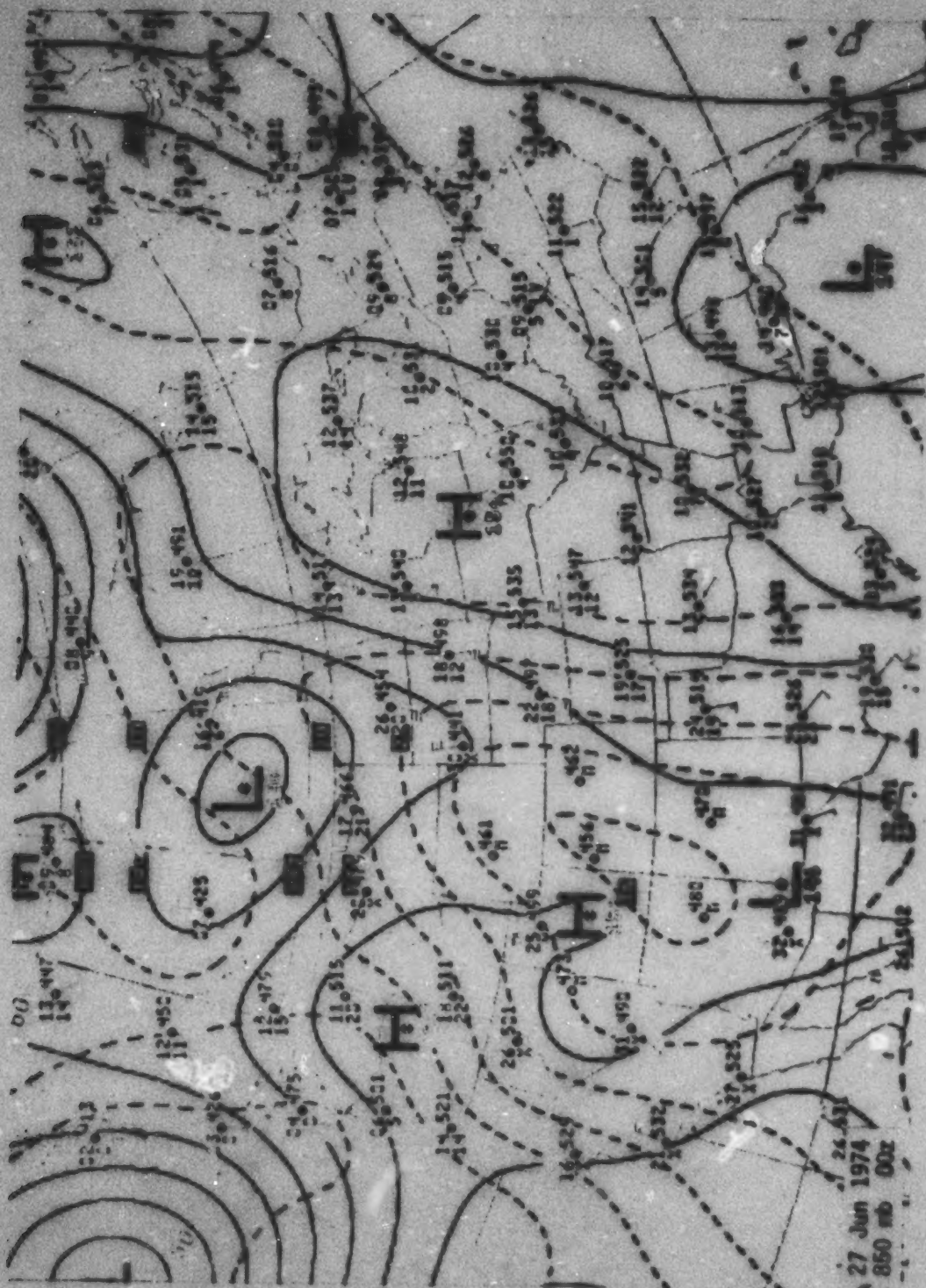
30 JUL 1974
BSDB ANALYSIS

Base map type B(8505)



8 JUL 1974
USOPB ANALYSIS

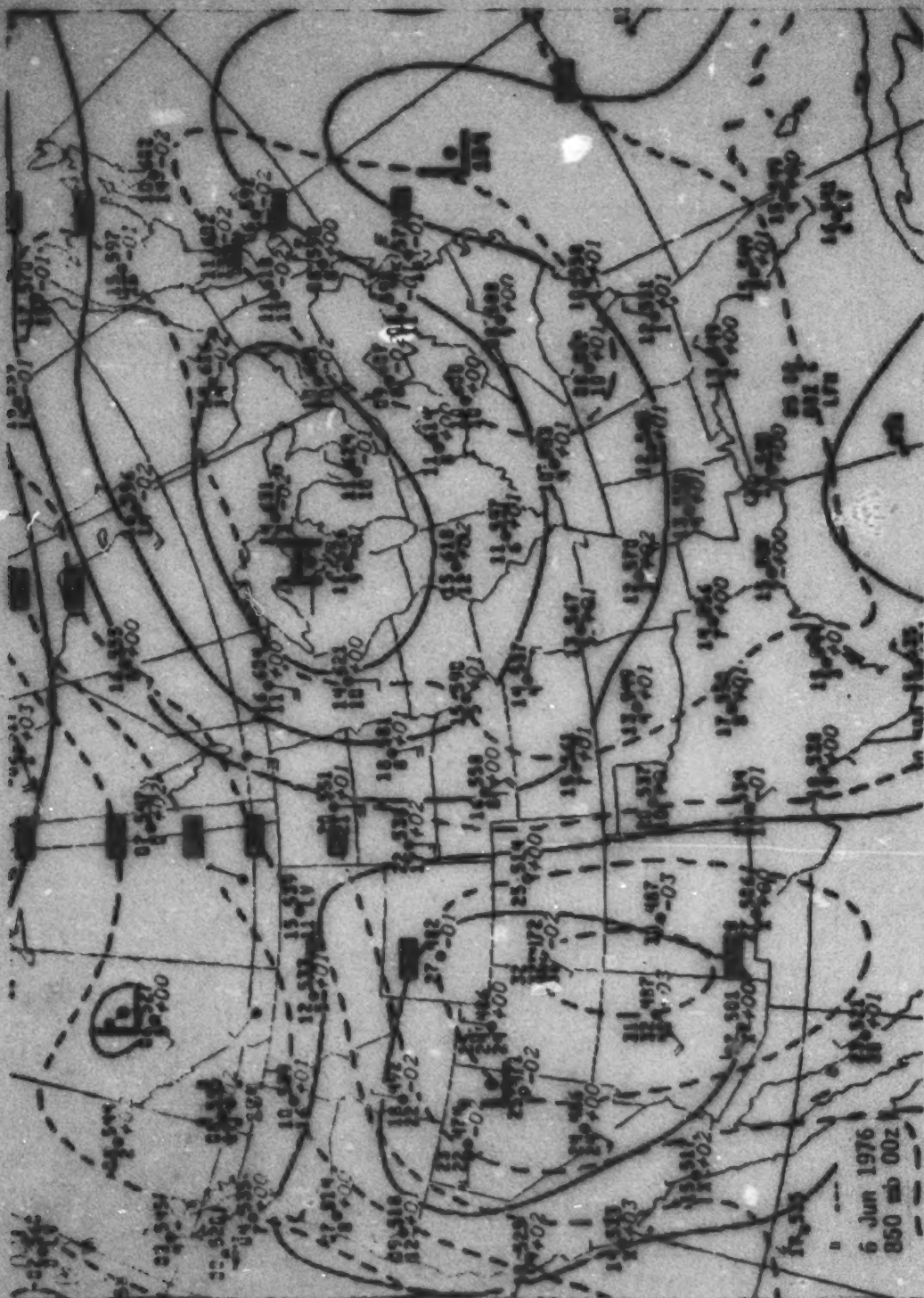
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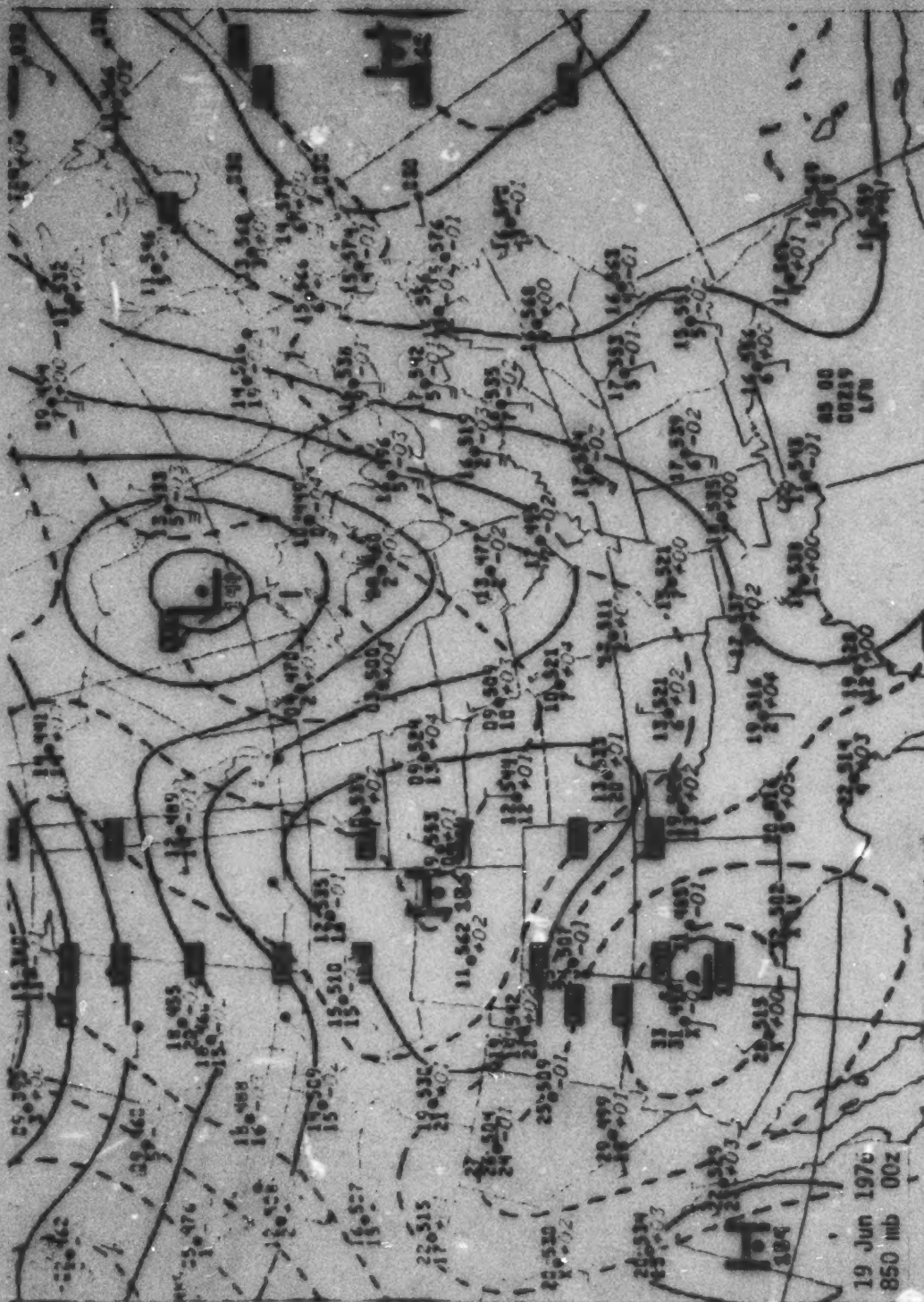
27 Jun 1974
850 mb 00z

Base map type D(850S)

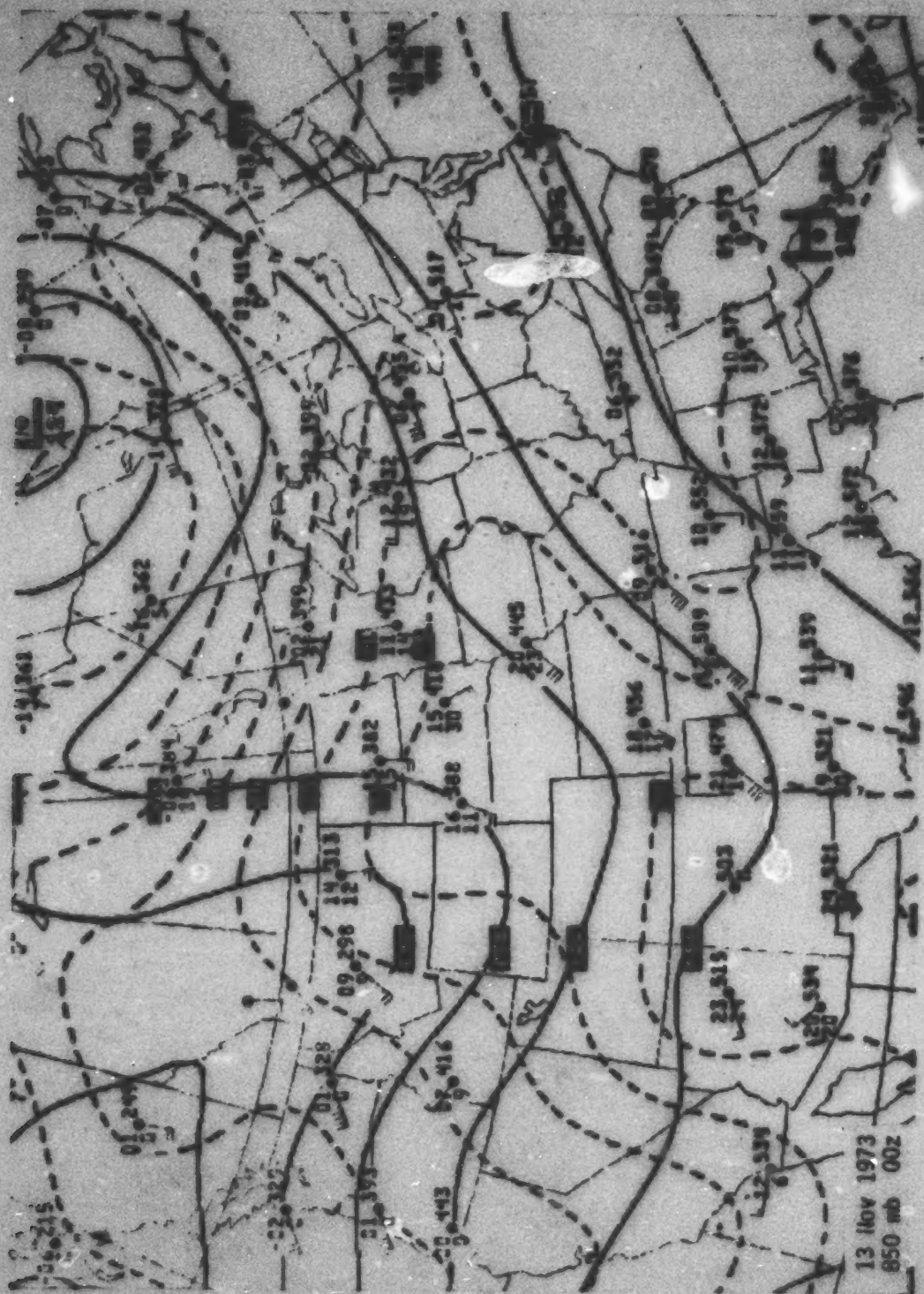
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best available copy.

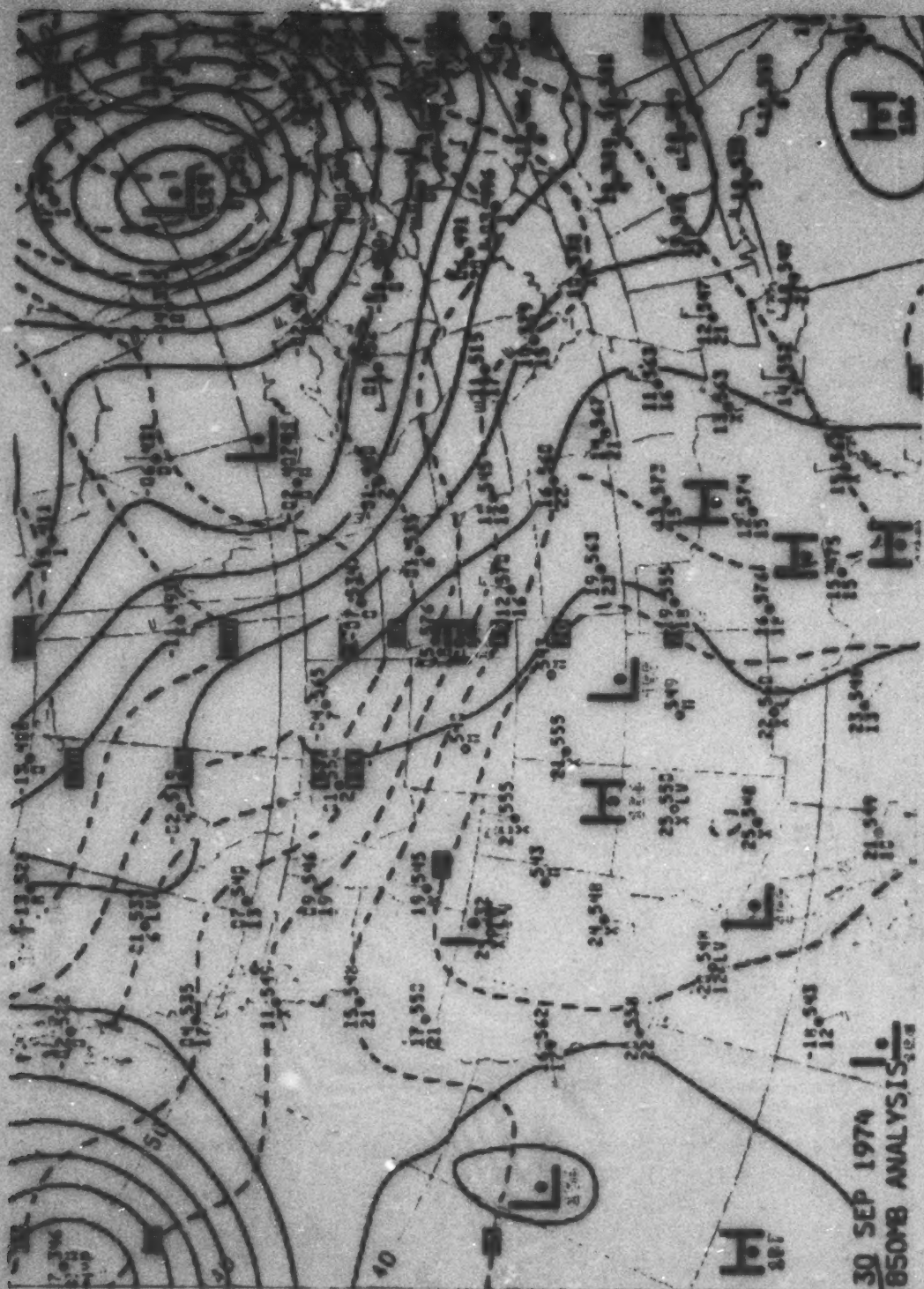


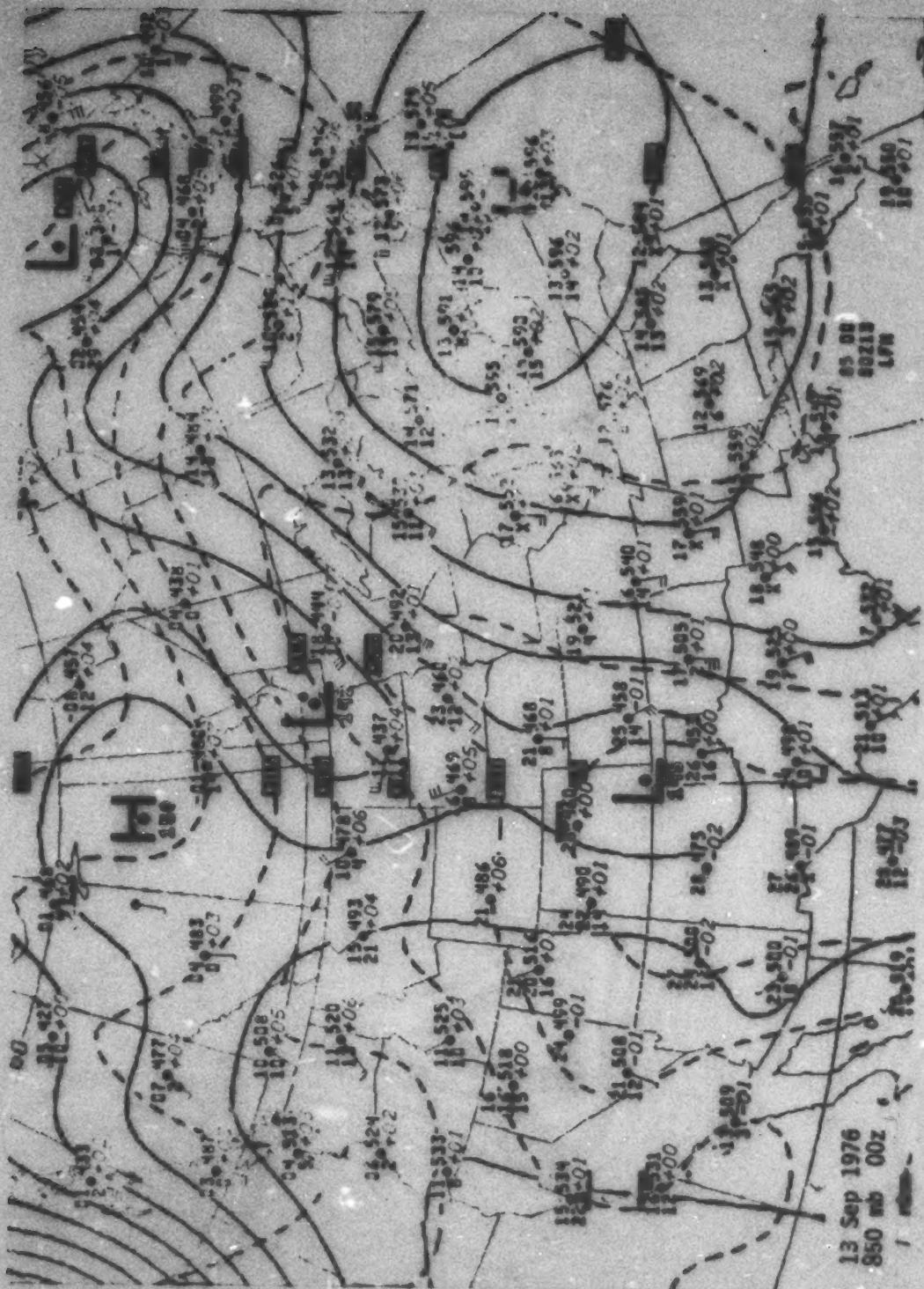
Base map type E(050S)



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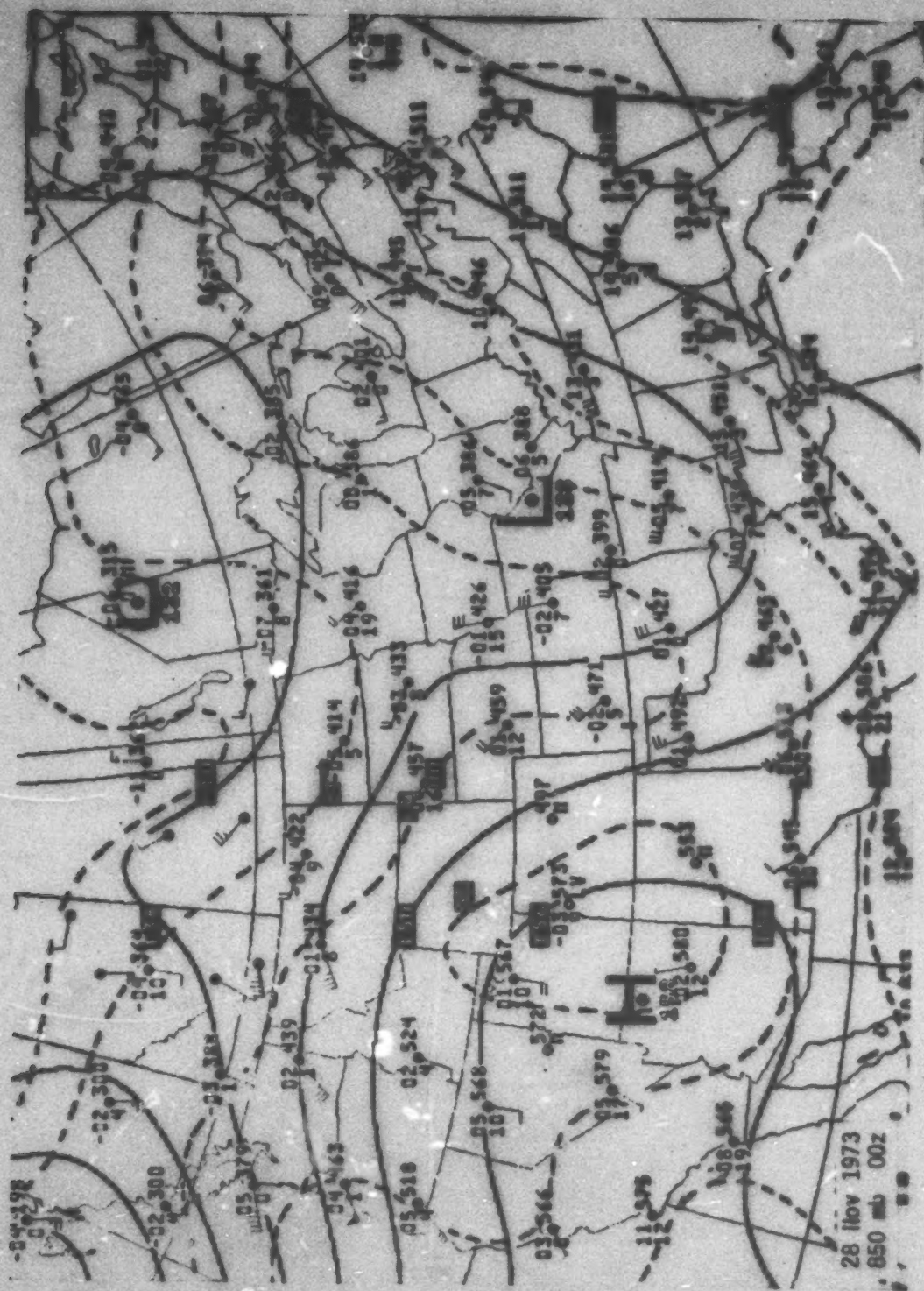






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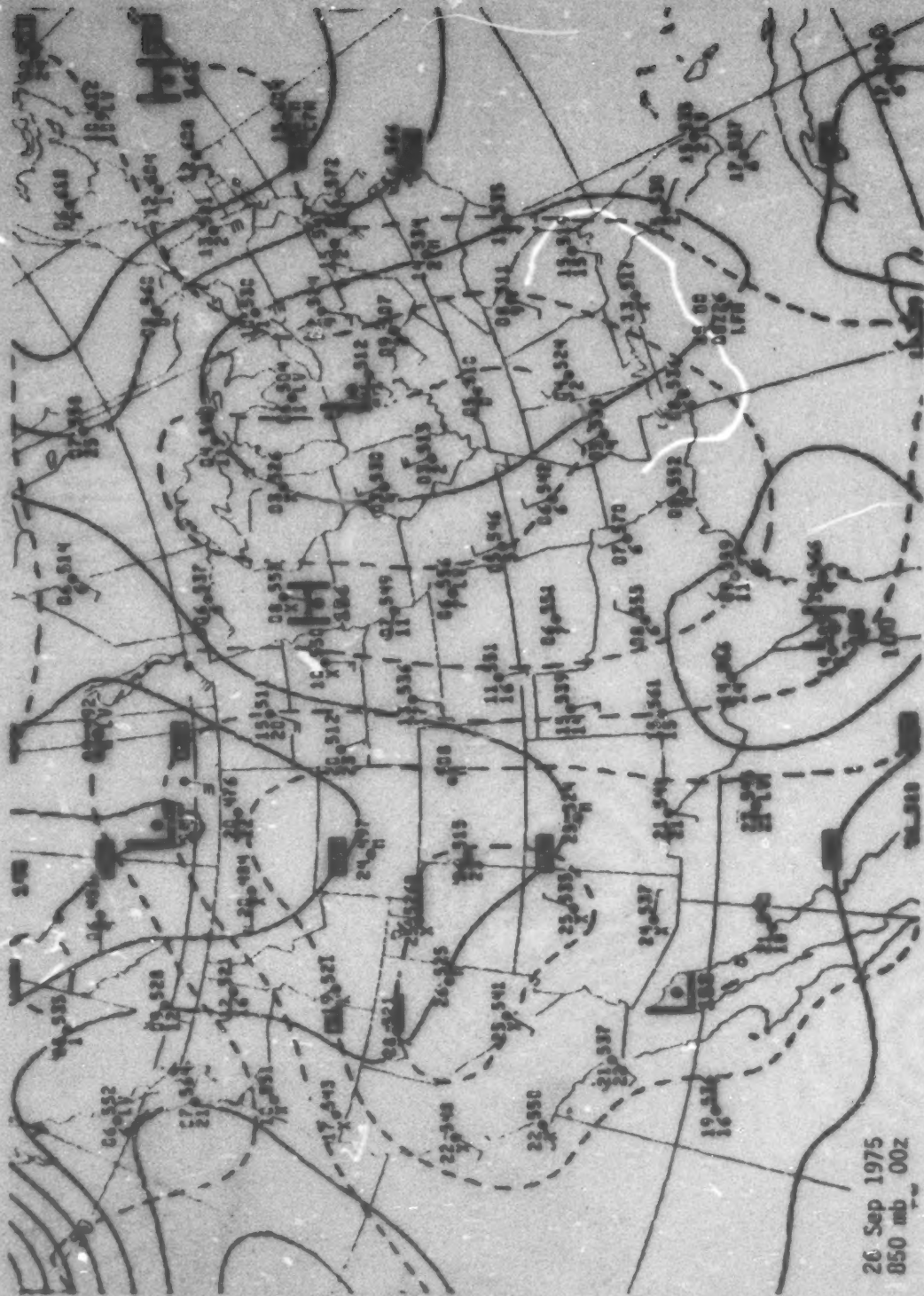
Reproduced from
best available copy.



28 Nov 1973

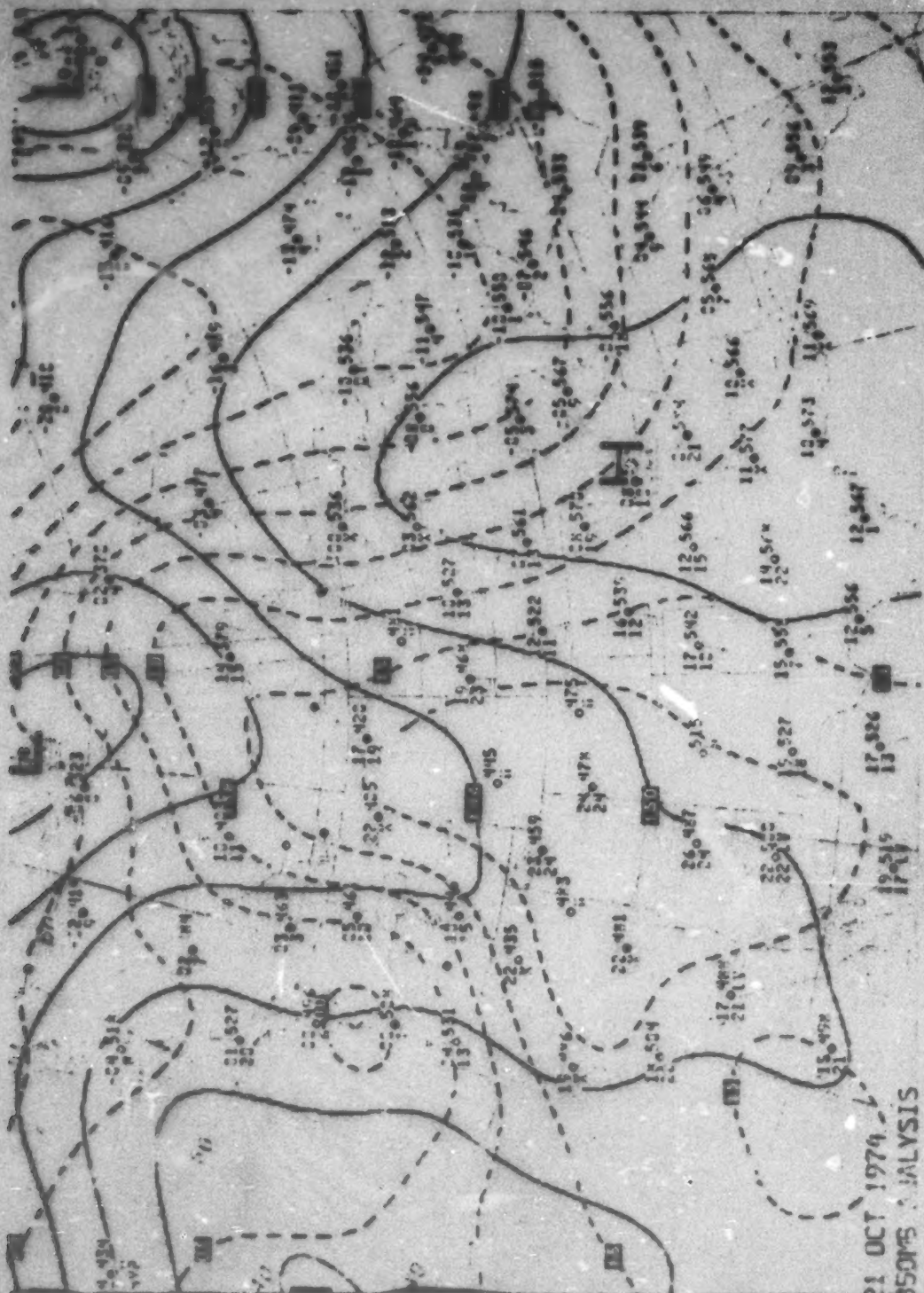
850 mb 00z

Base map type D(850F)



26 Sep 1975
050 mb 00z

Base map type E(850F)



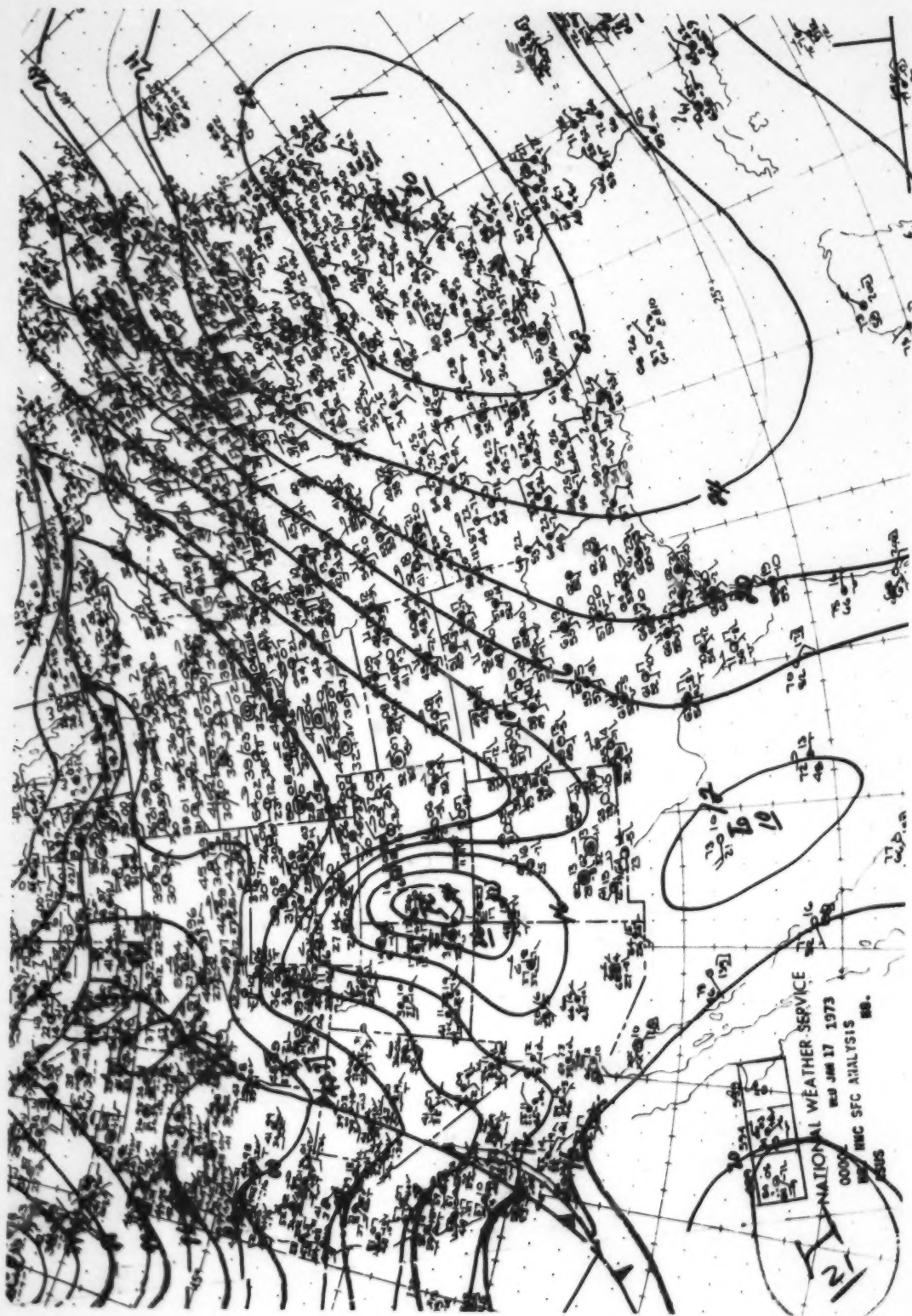
21 OCT 1974
550PS ANALYSIS

Base map type F(850F)

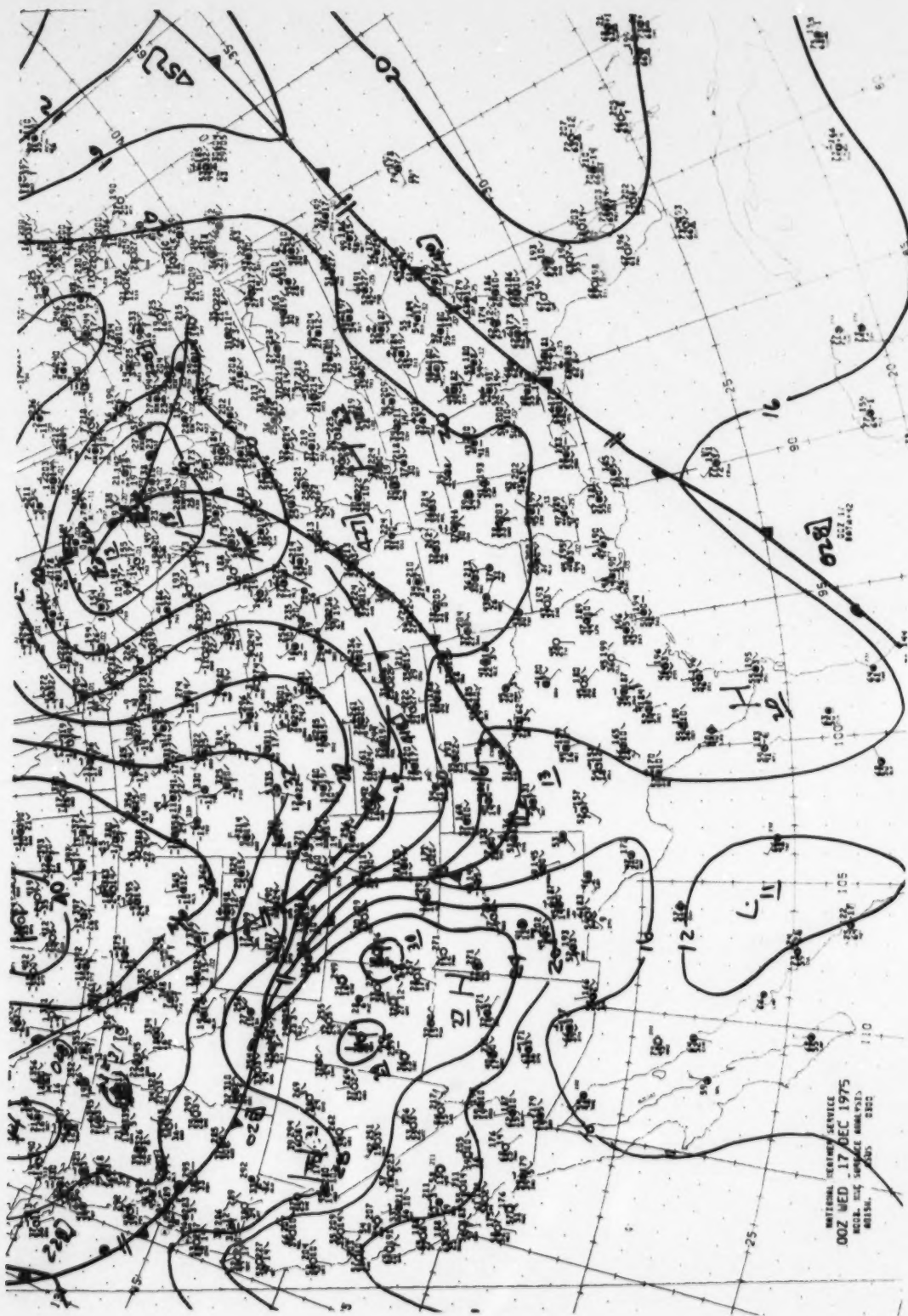
APPENDIX B

SECTION 2

BASE MAPS FOR GEOSTROPHIC WIND



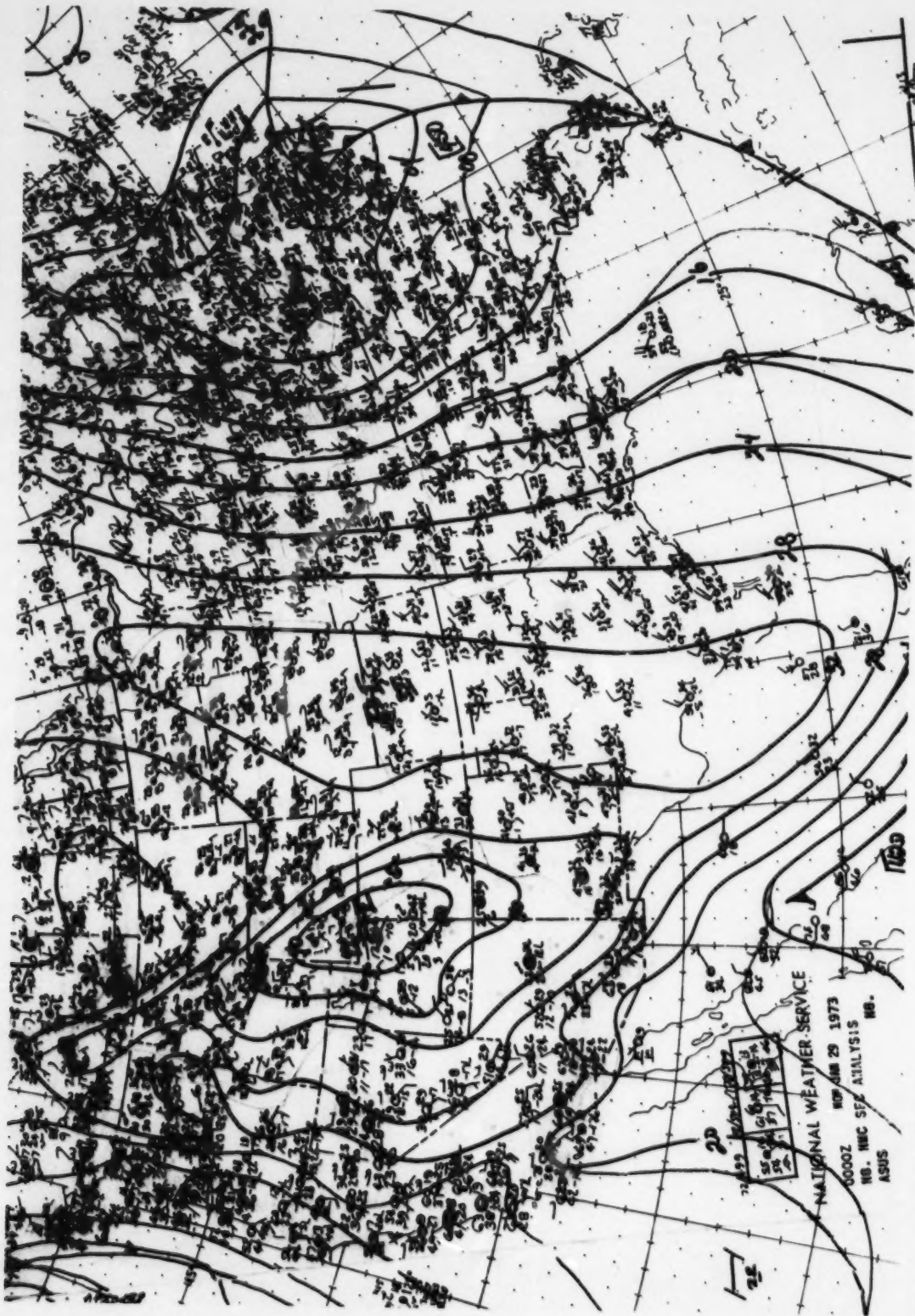
Base map type A(Geow)



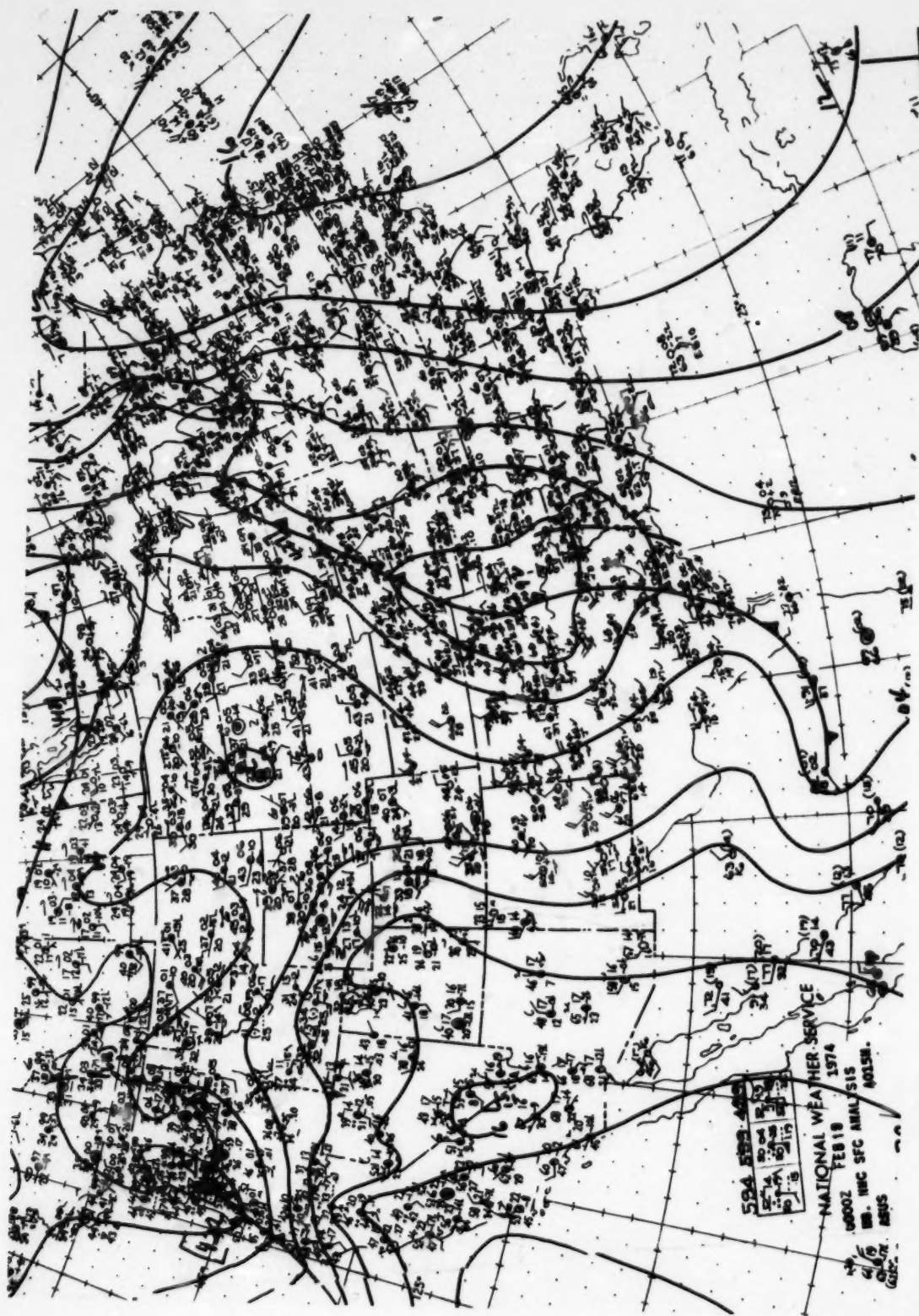
Reproduced from
best available copy.

Base map type B(Geow)

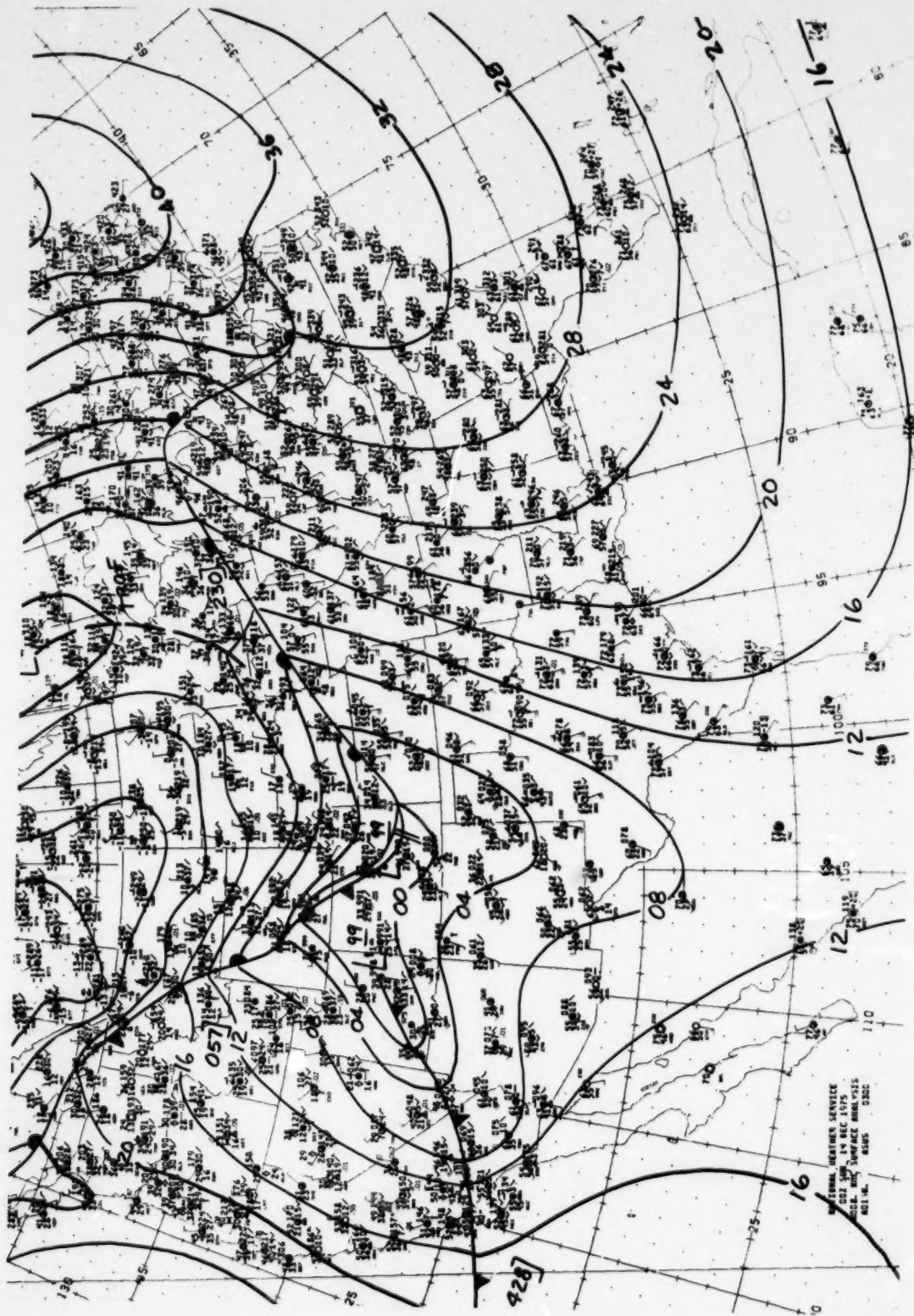
NATIONAL GEOSAT SERVICE
DOZ MED 17 DEC 1975
MILES 1:4 SCALE MAPS
MILES 1:4

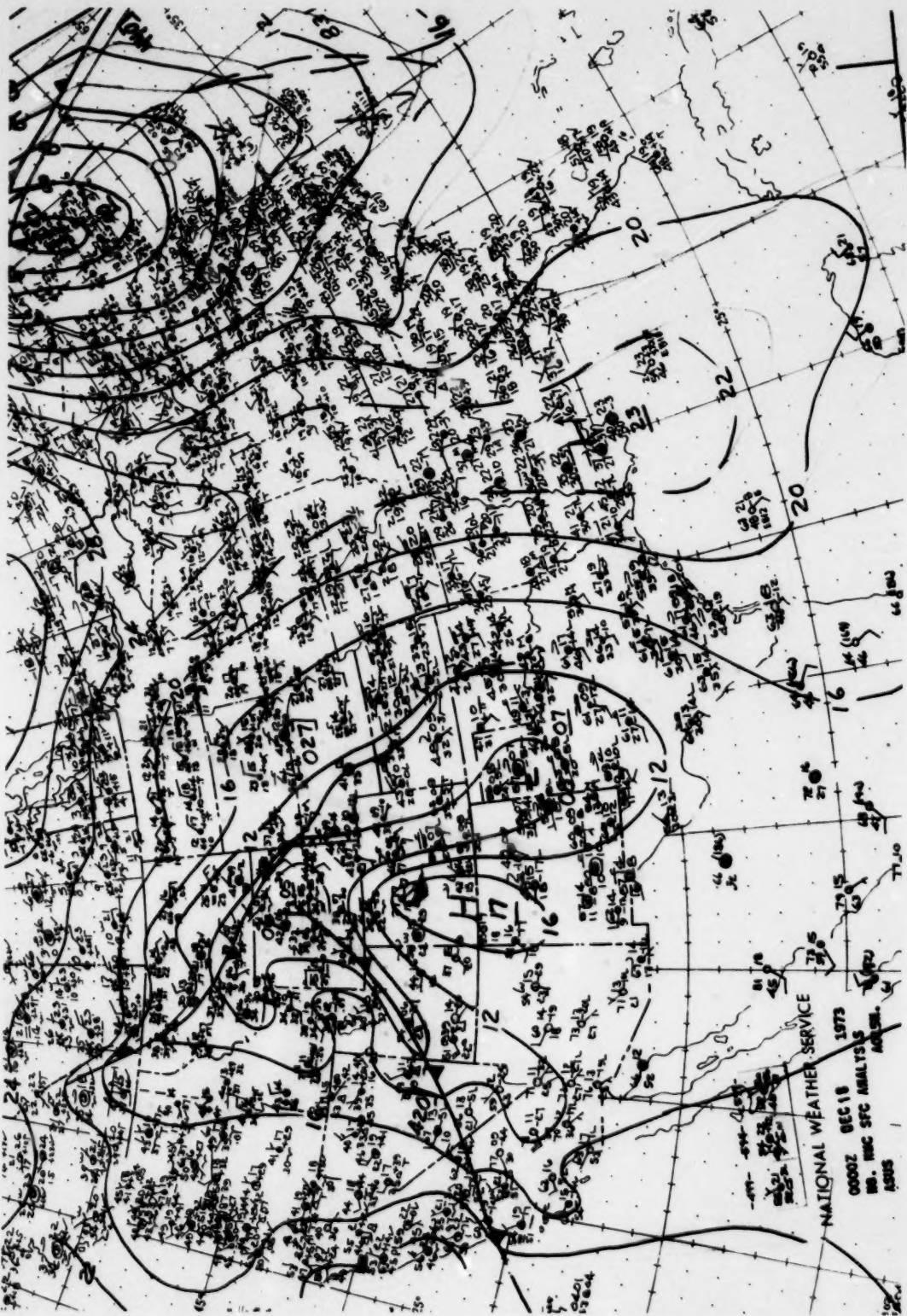


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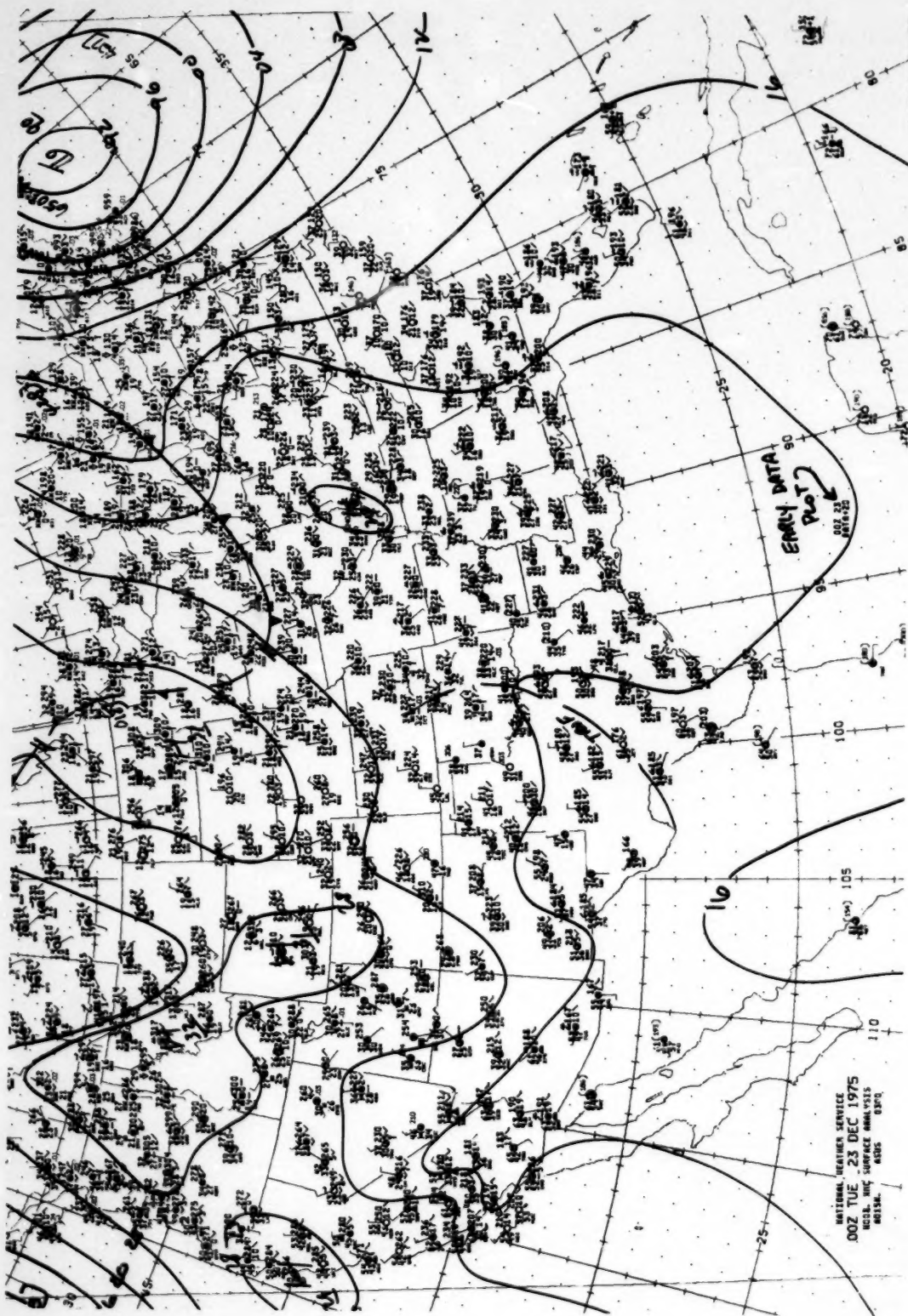


Base map type E(Geow)

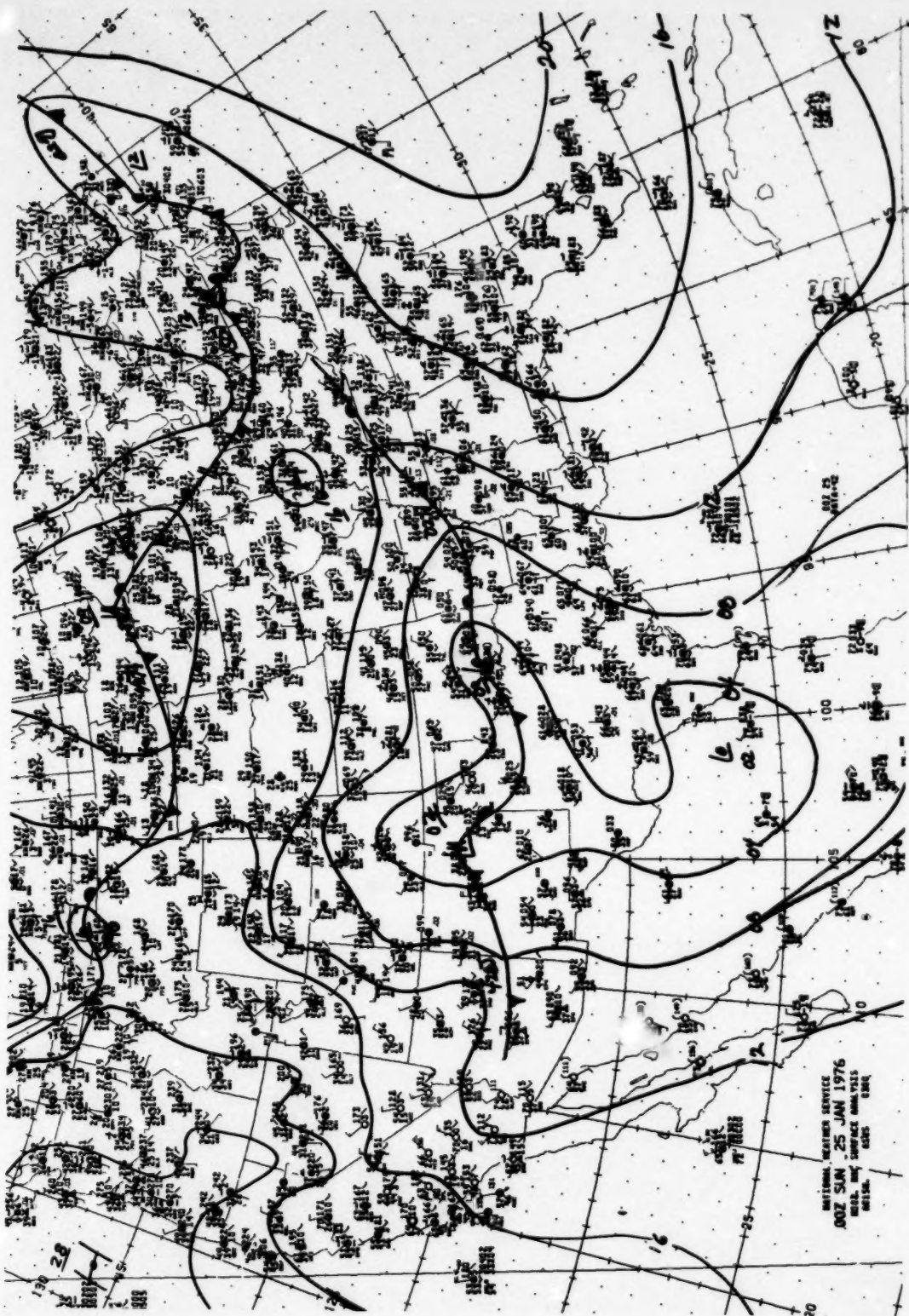




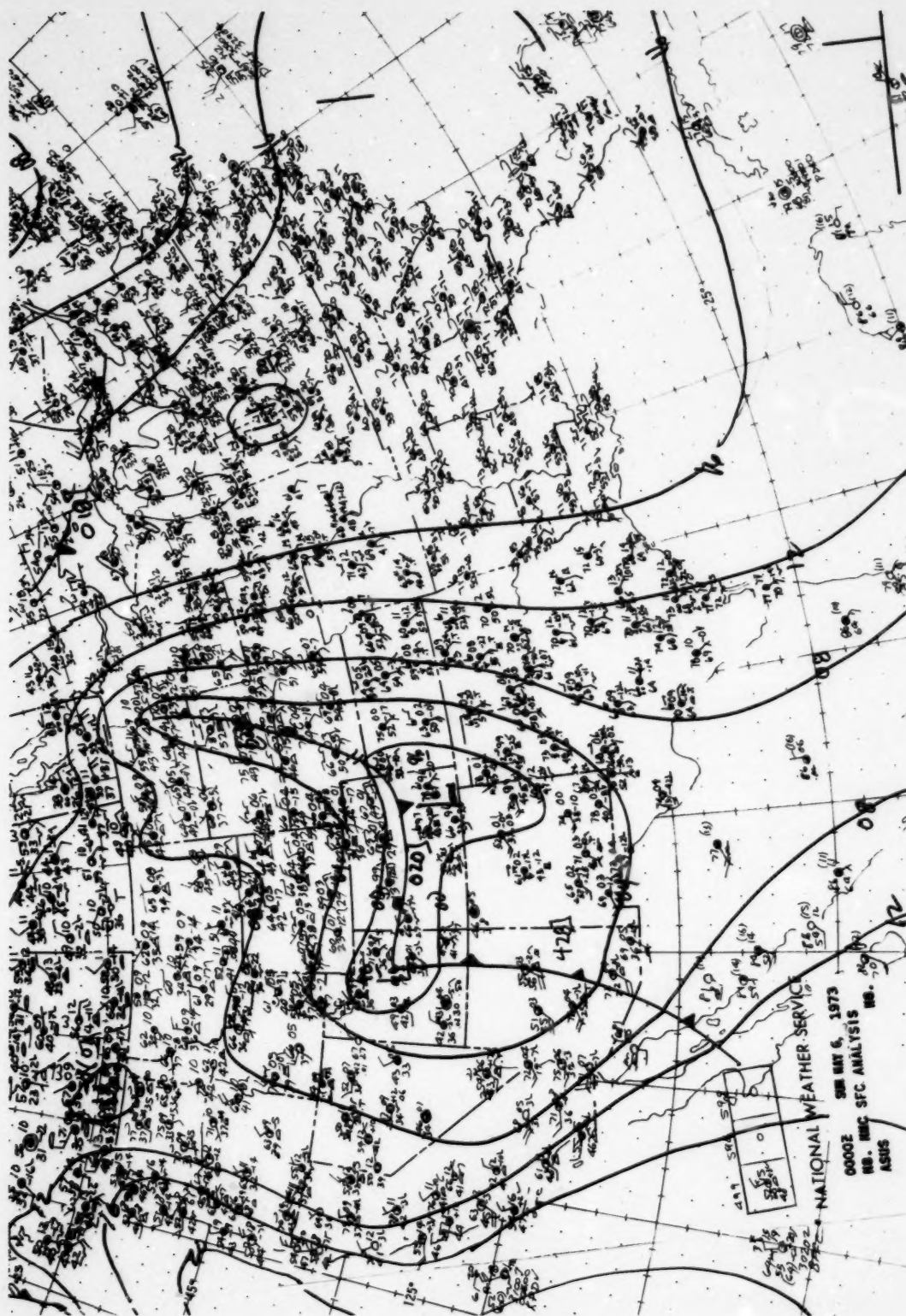
Base map type G(Geow)

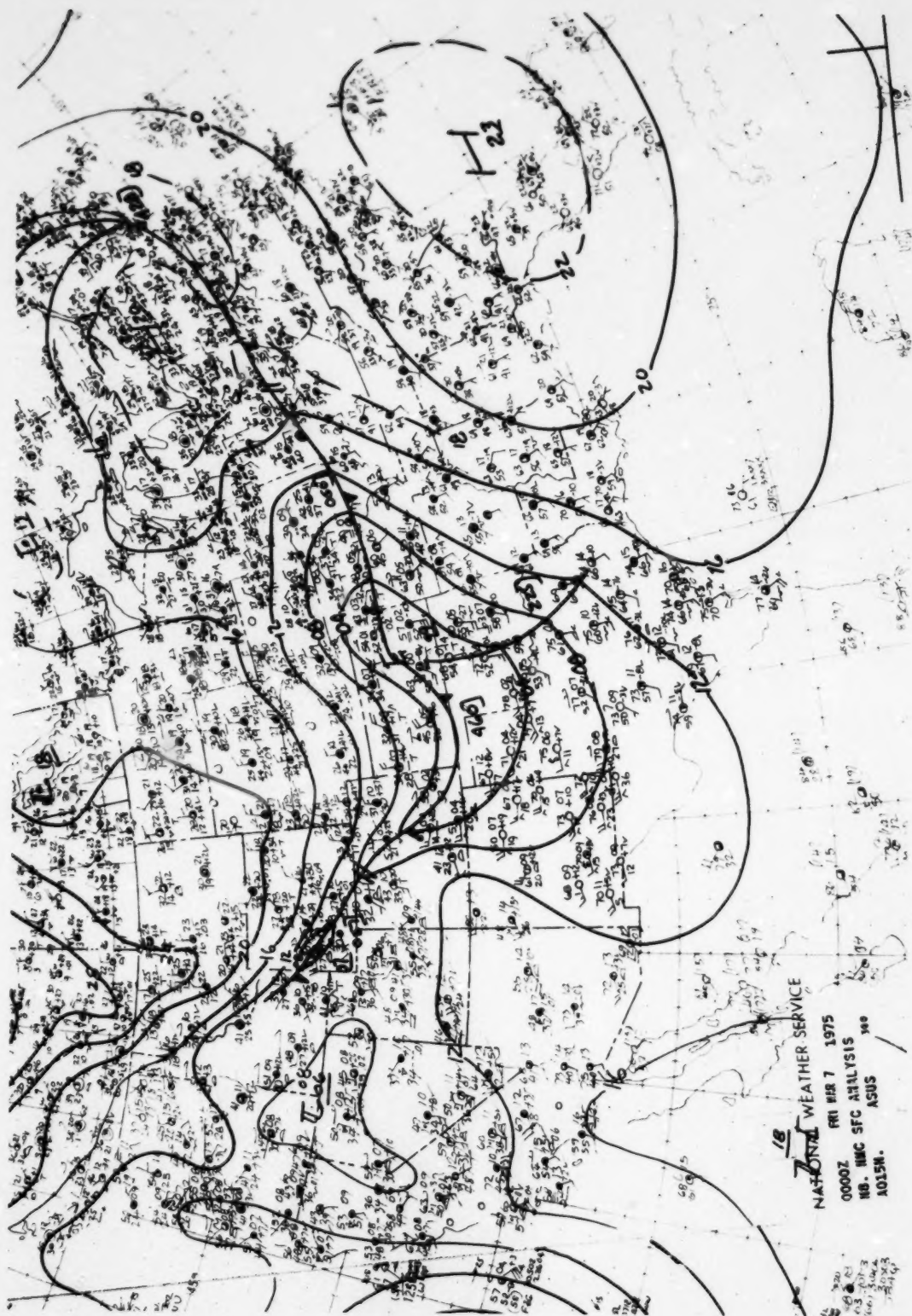


Base map type H(Geow)



Base map type I (Geow)

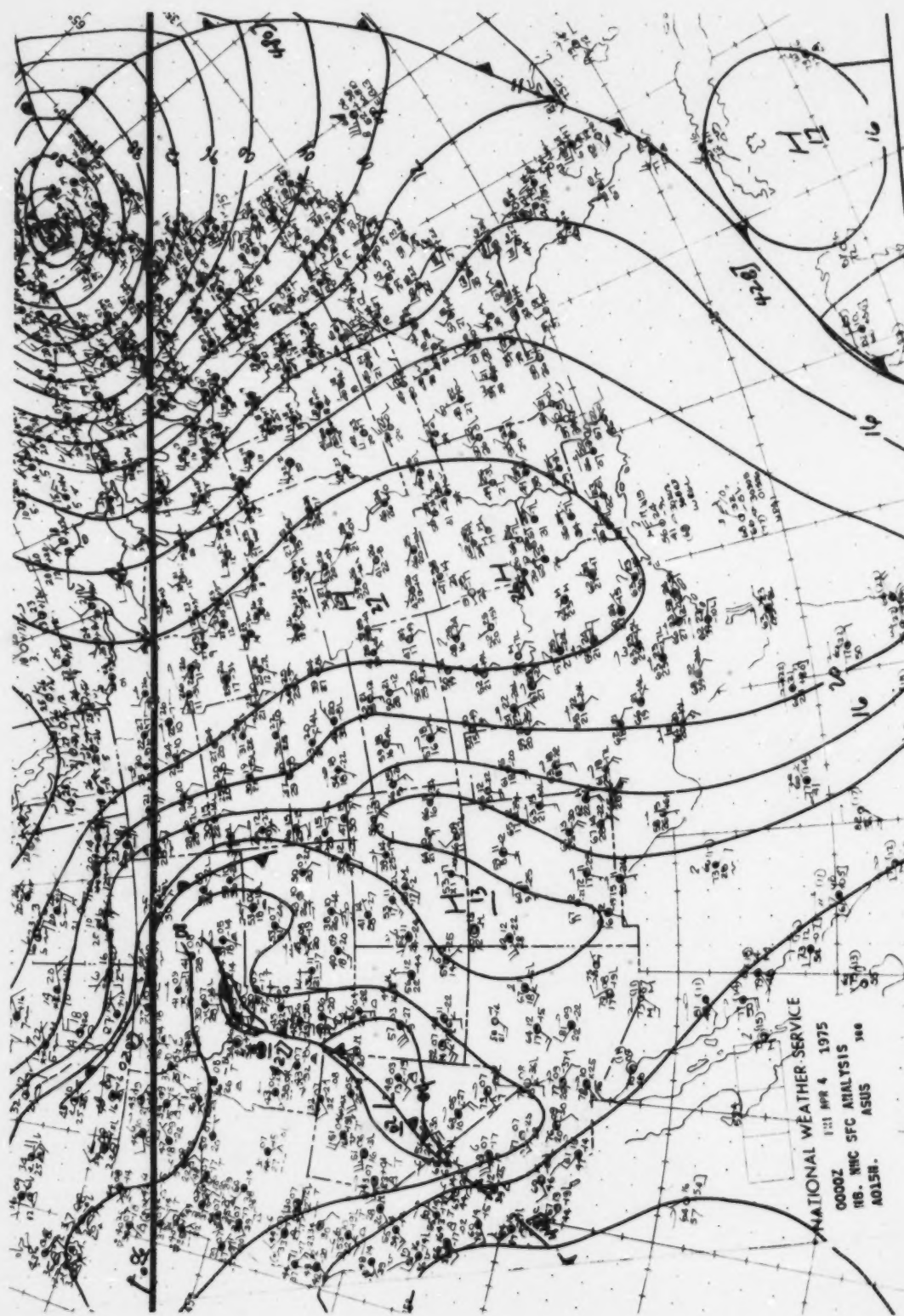




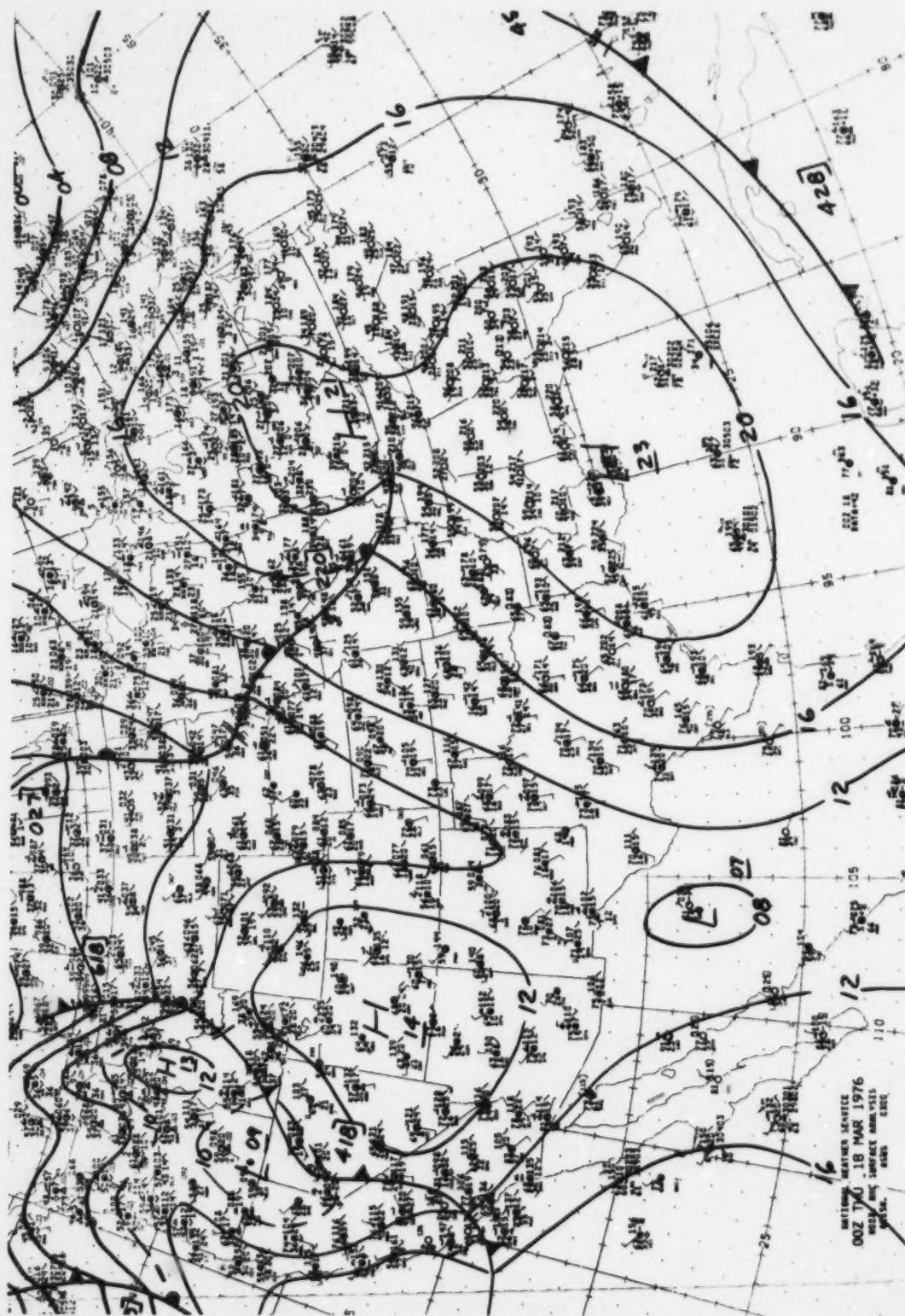
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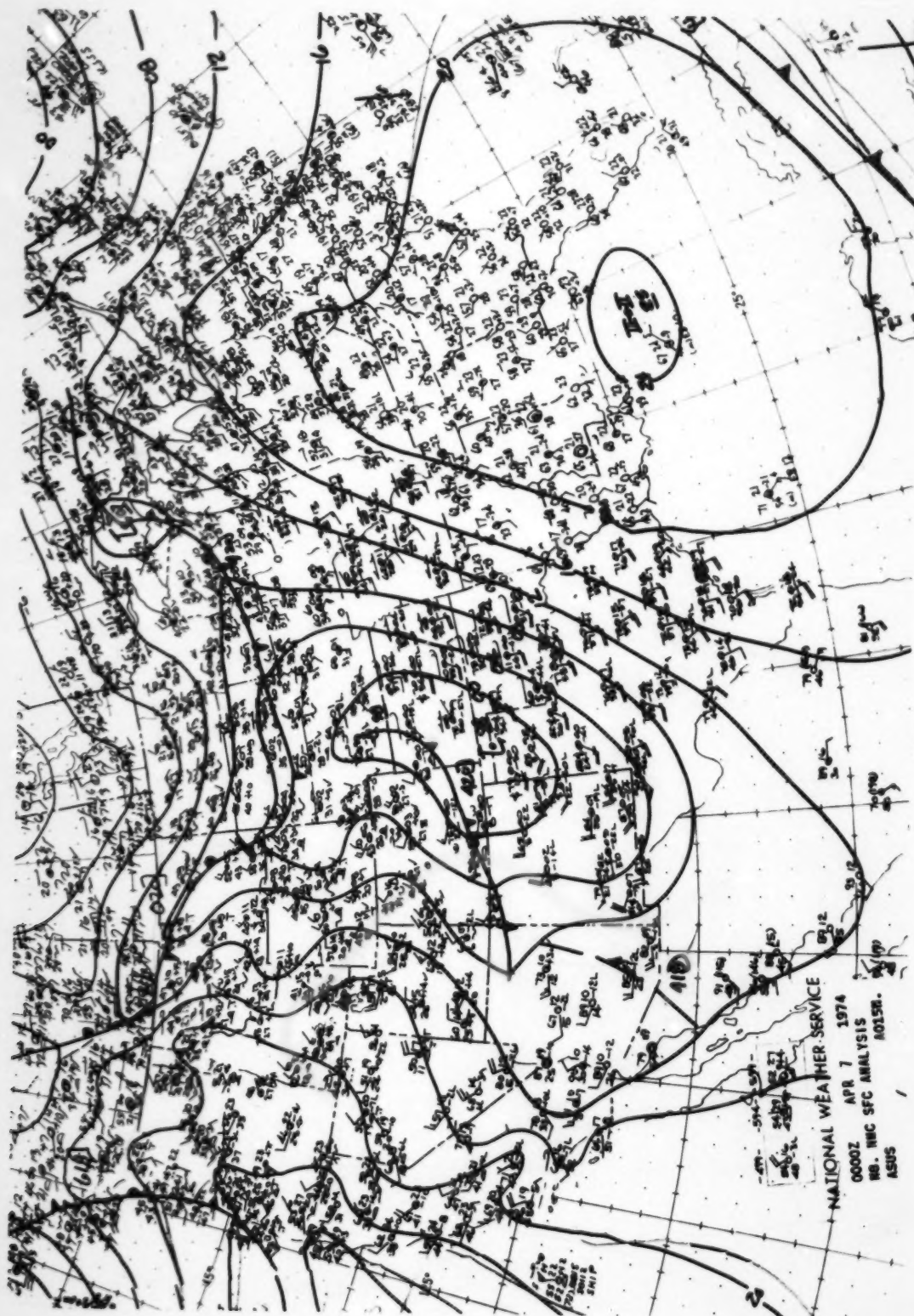
Base map type B(GeoSP)

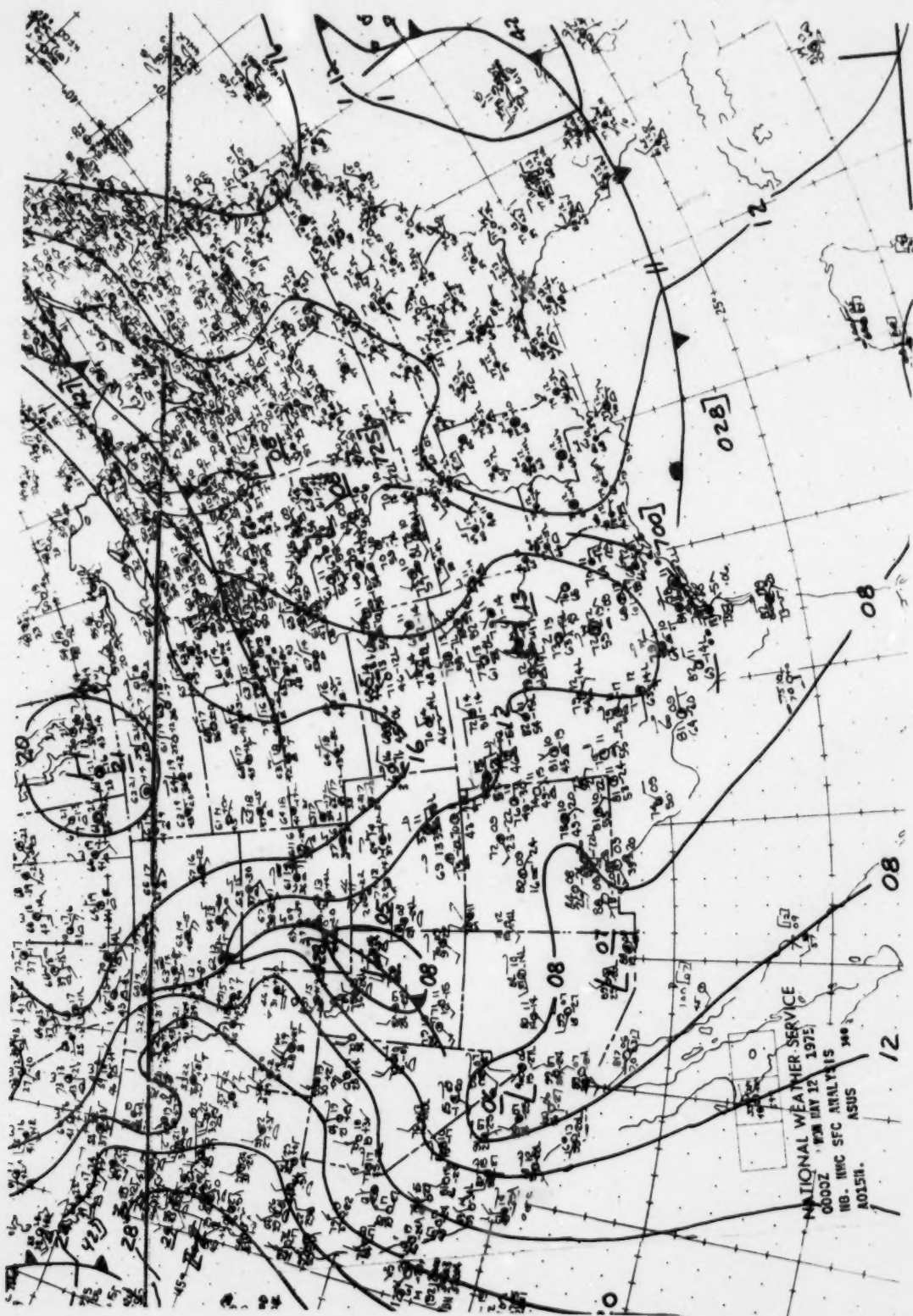
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Base map type C(GeoSP)



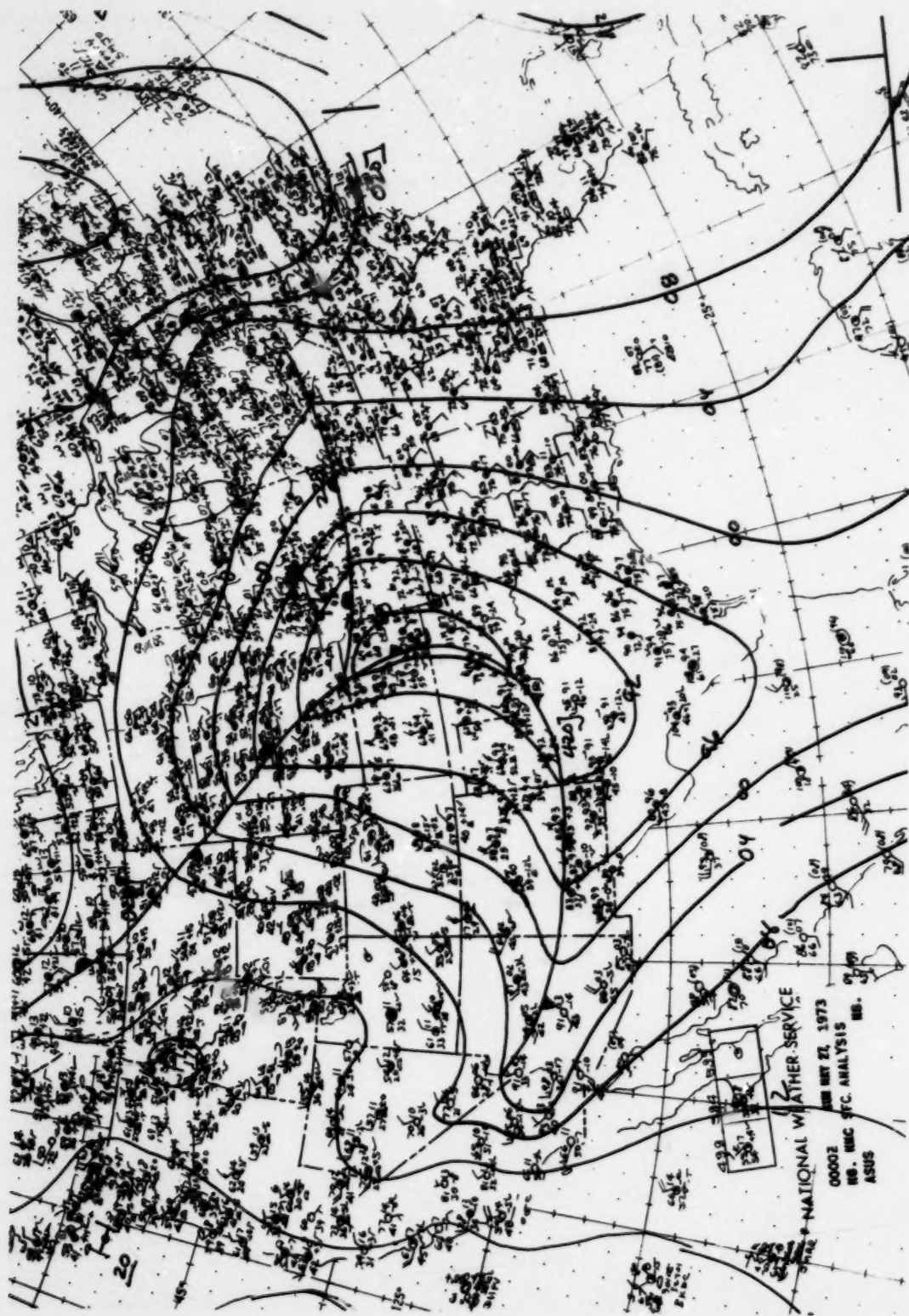


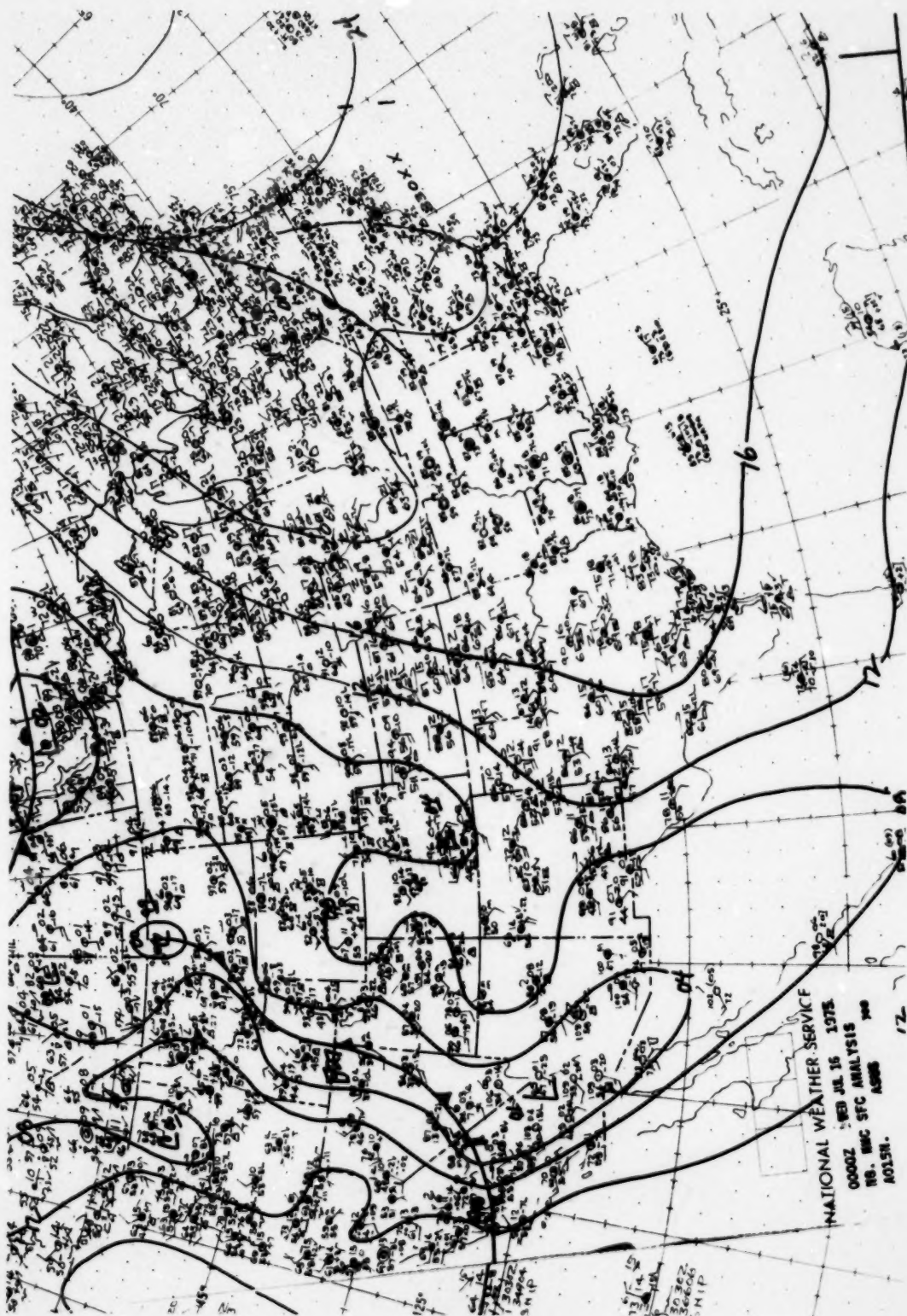


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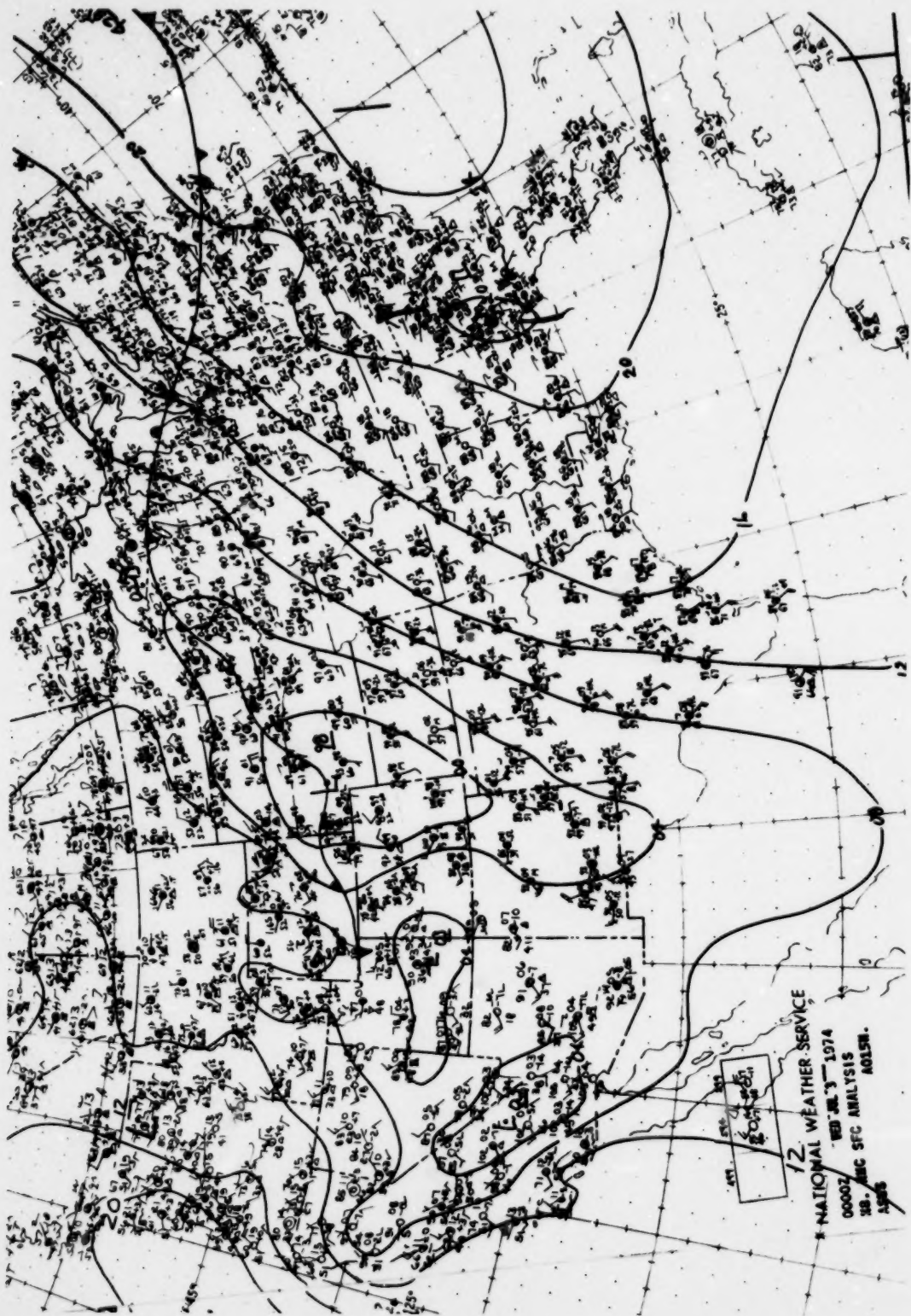


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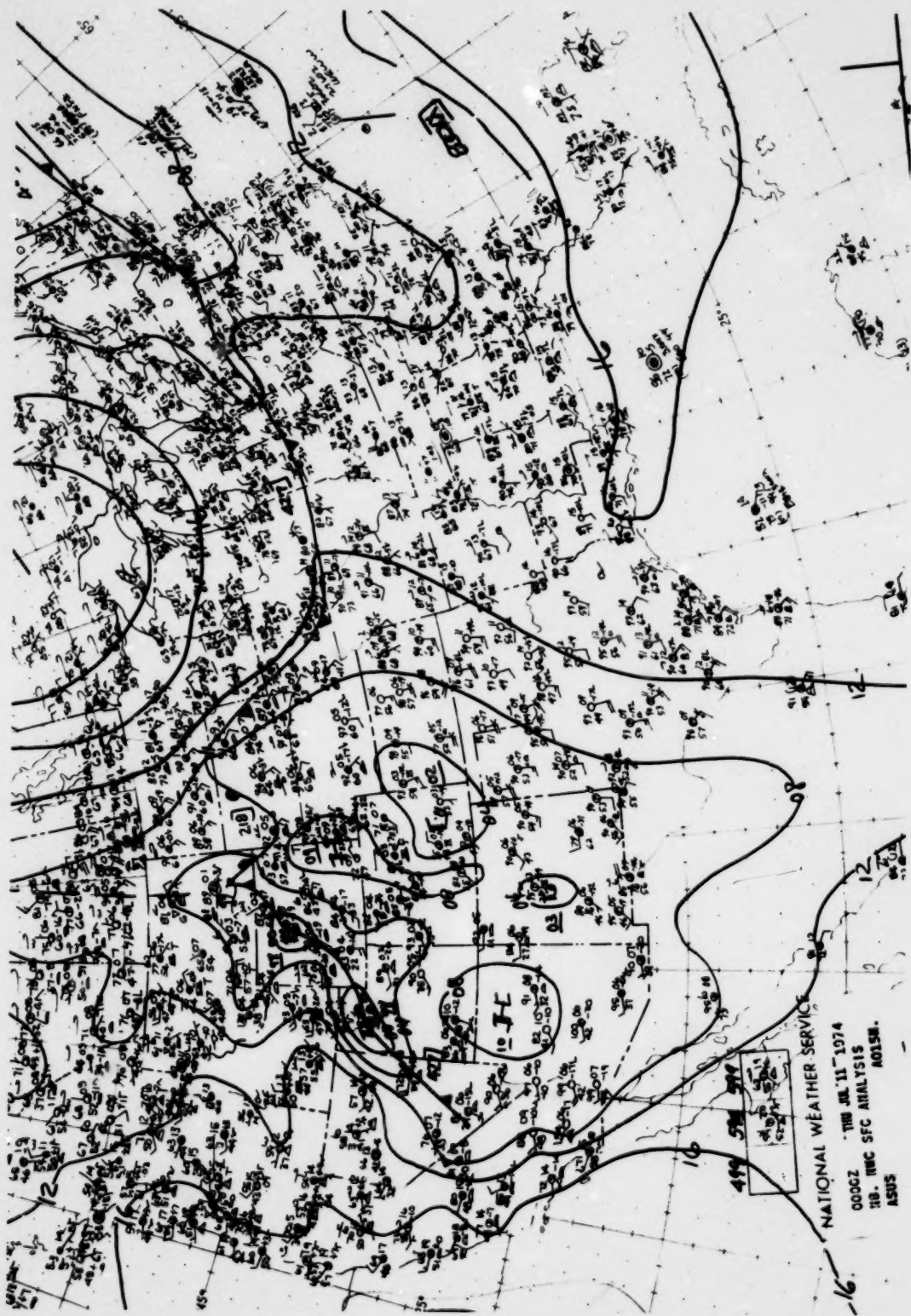


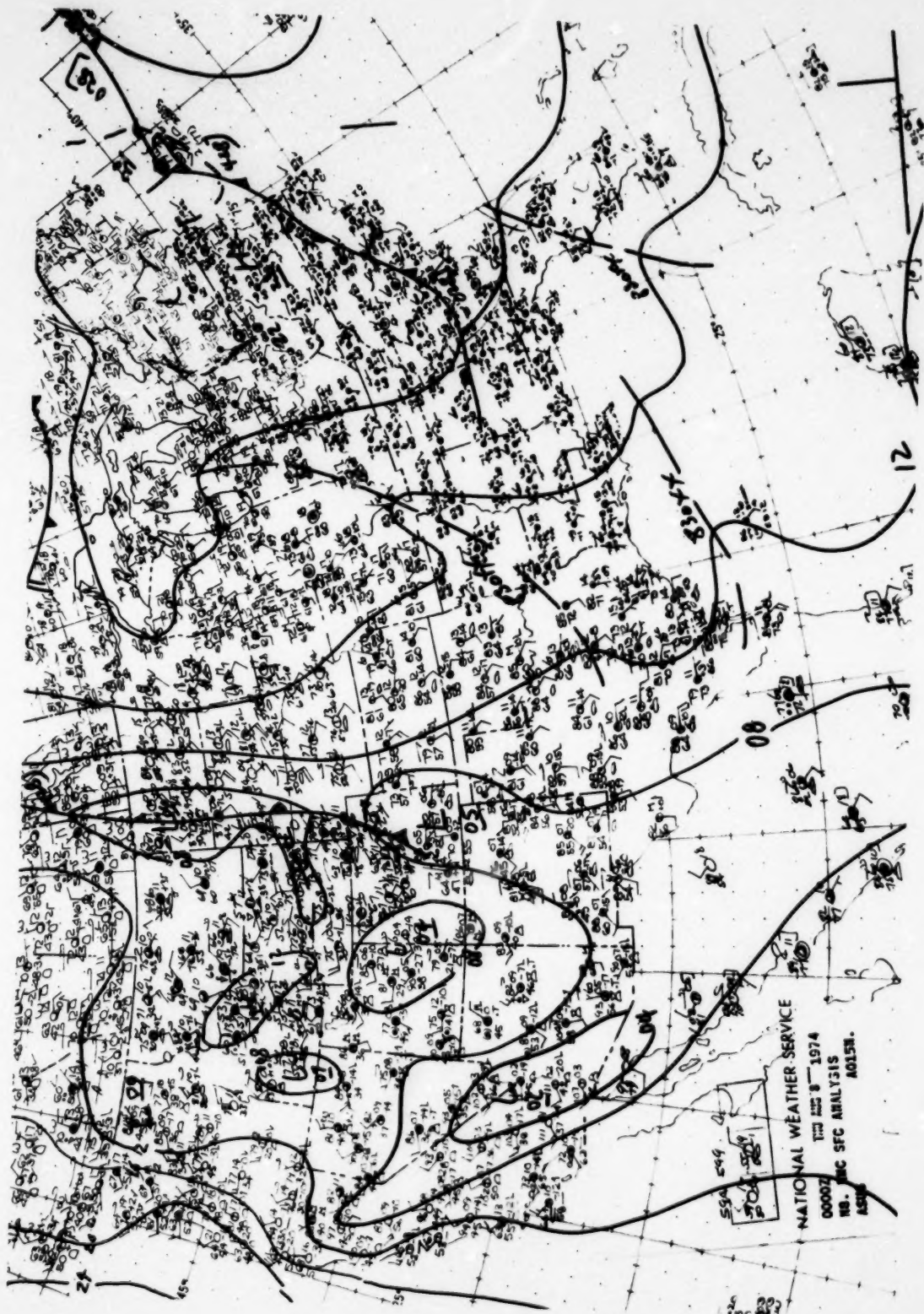


Base map type A(GeoS)



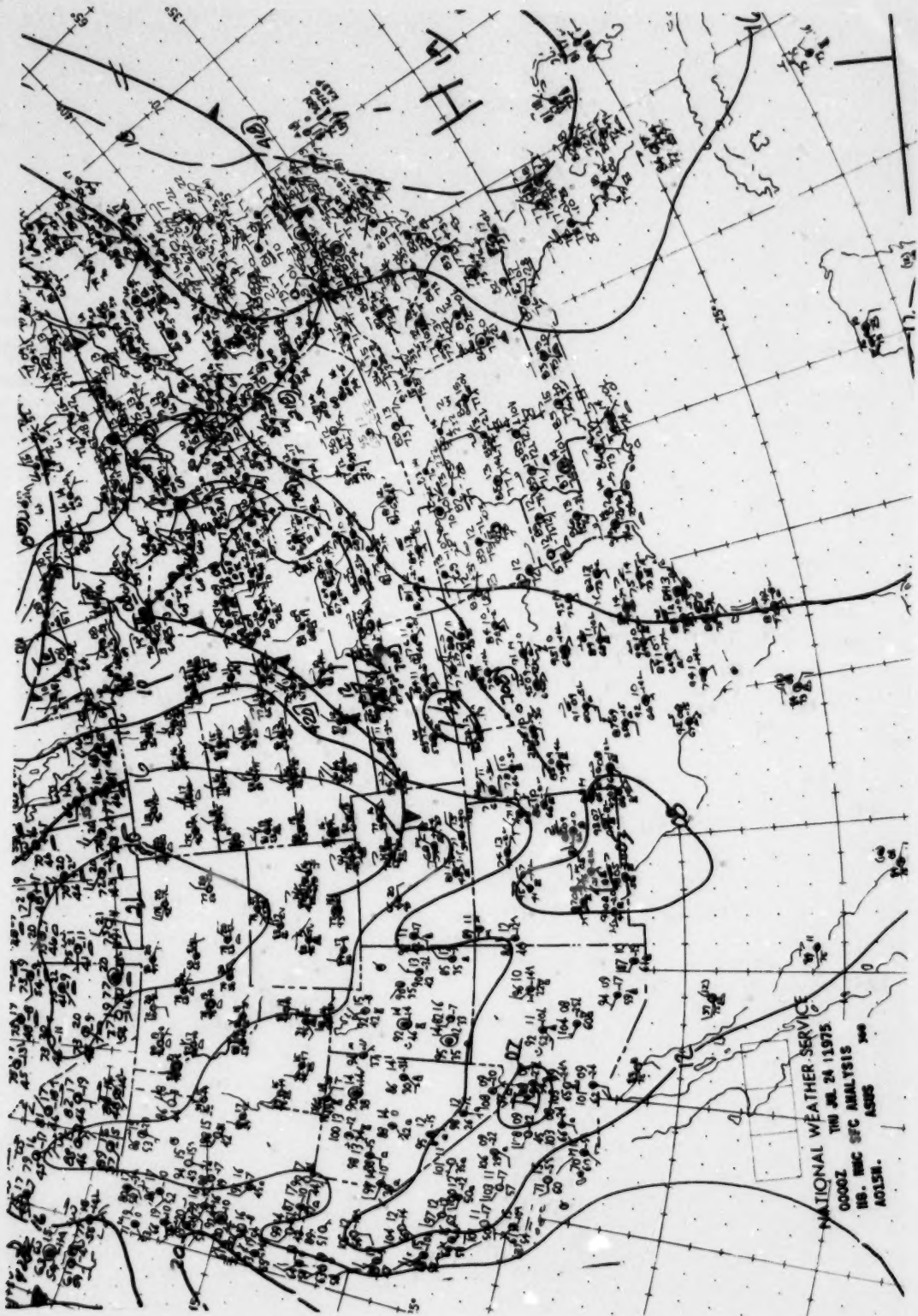
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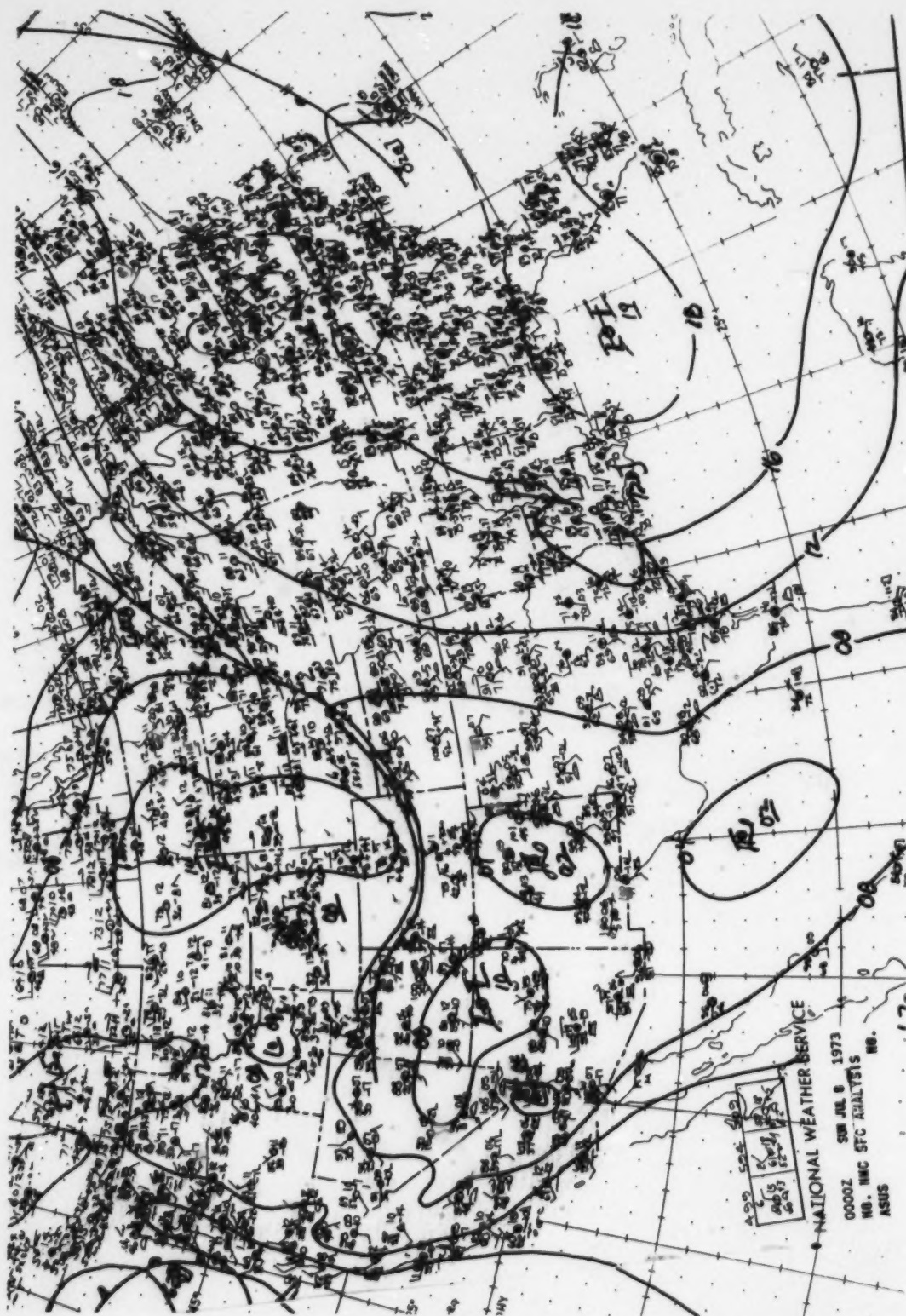


Base map type E(GeoS)





Base map type G(Geos)



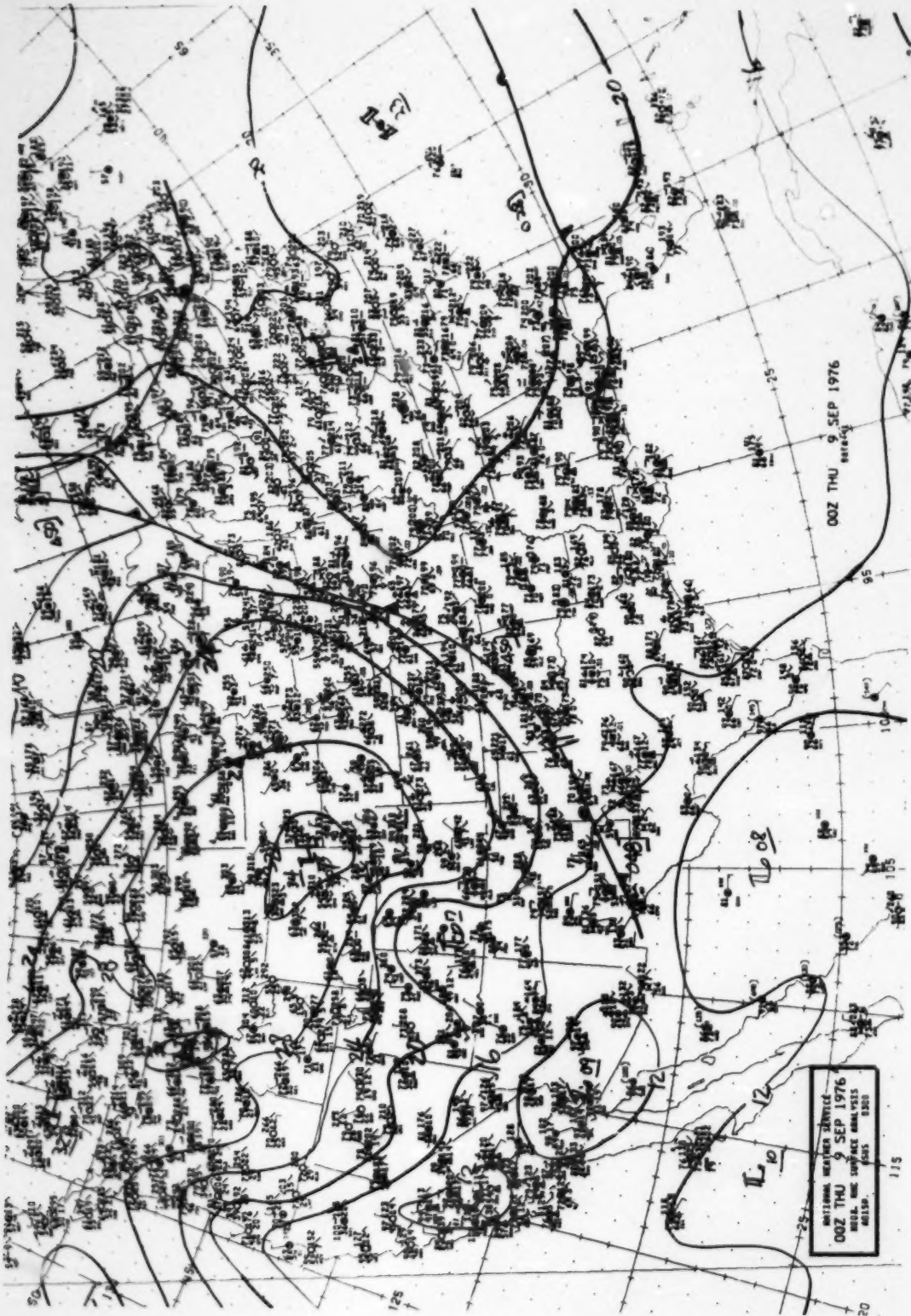
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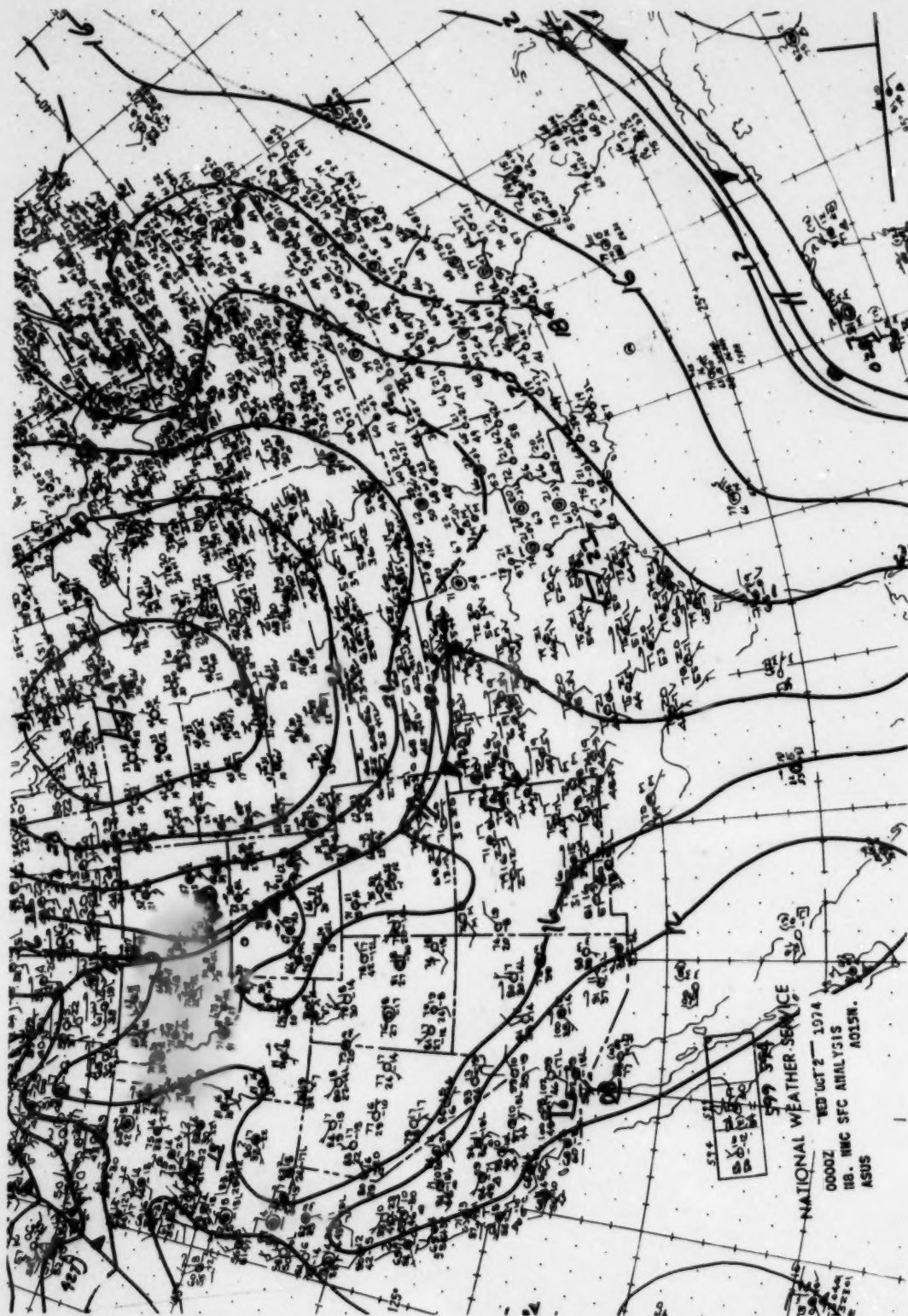
Base map type I(Geos)



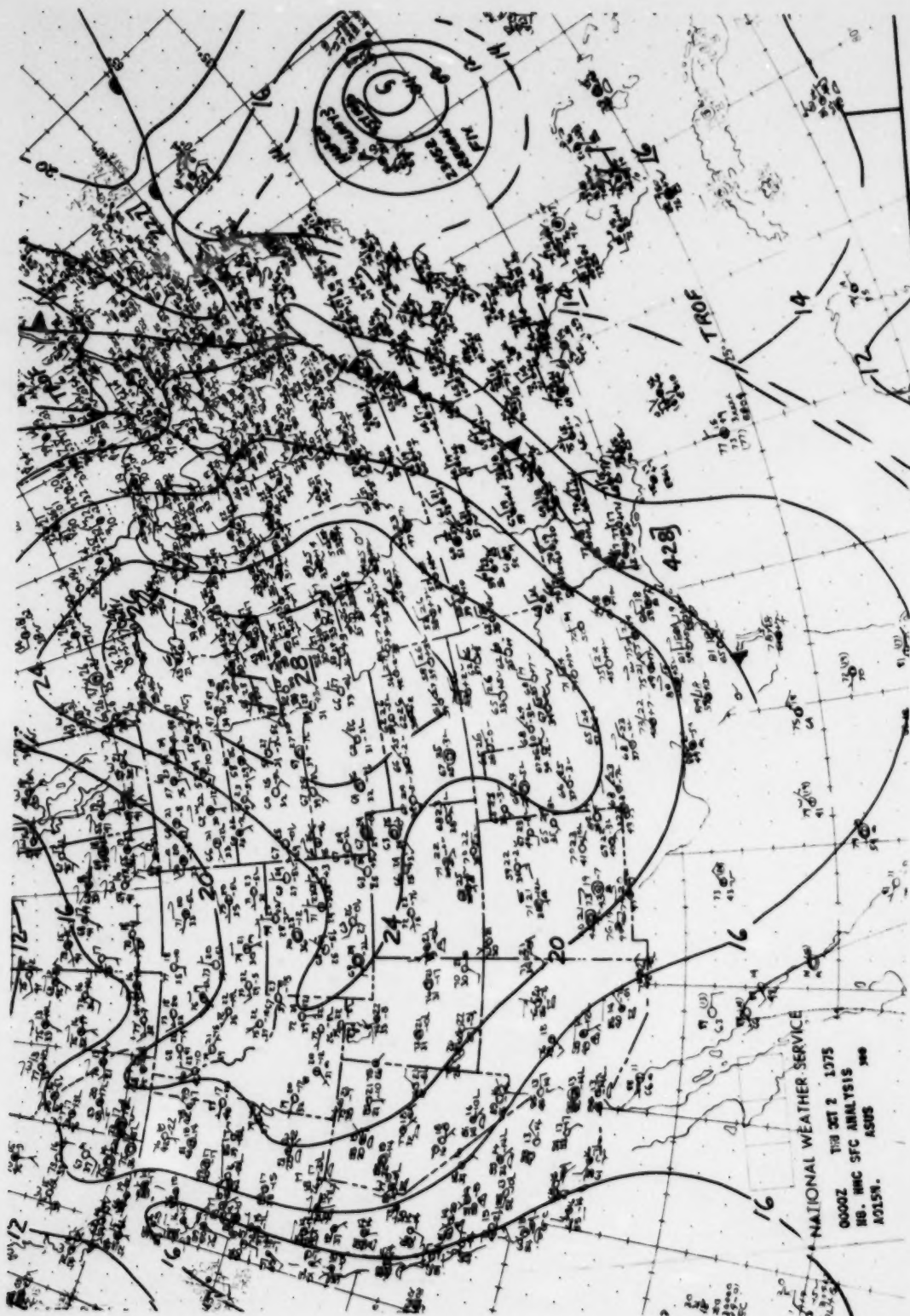
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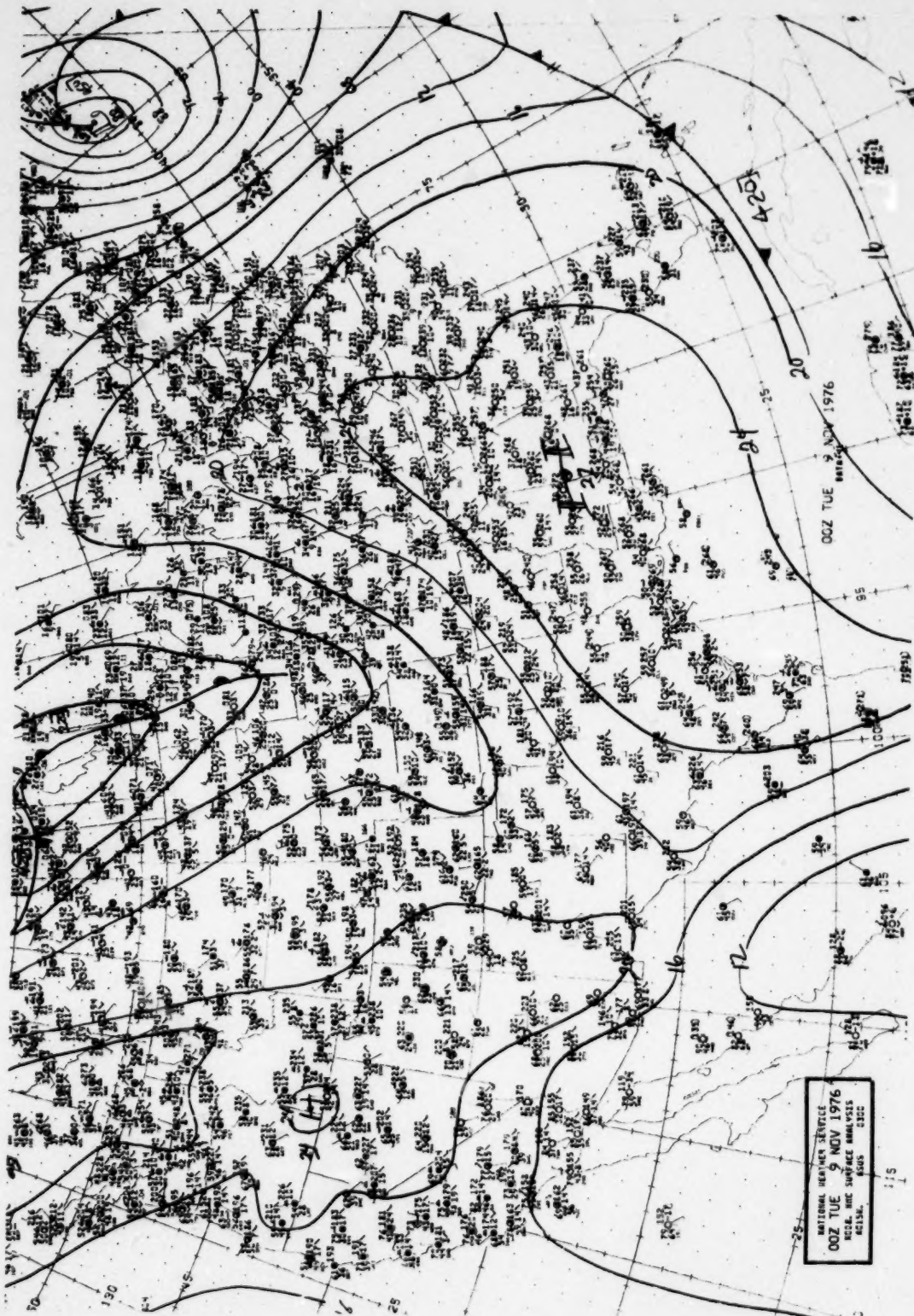
Base map type B(Geof)



Base map type C(GeoF)

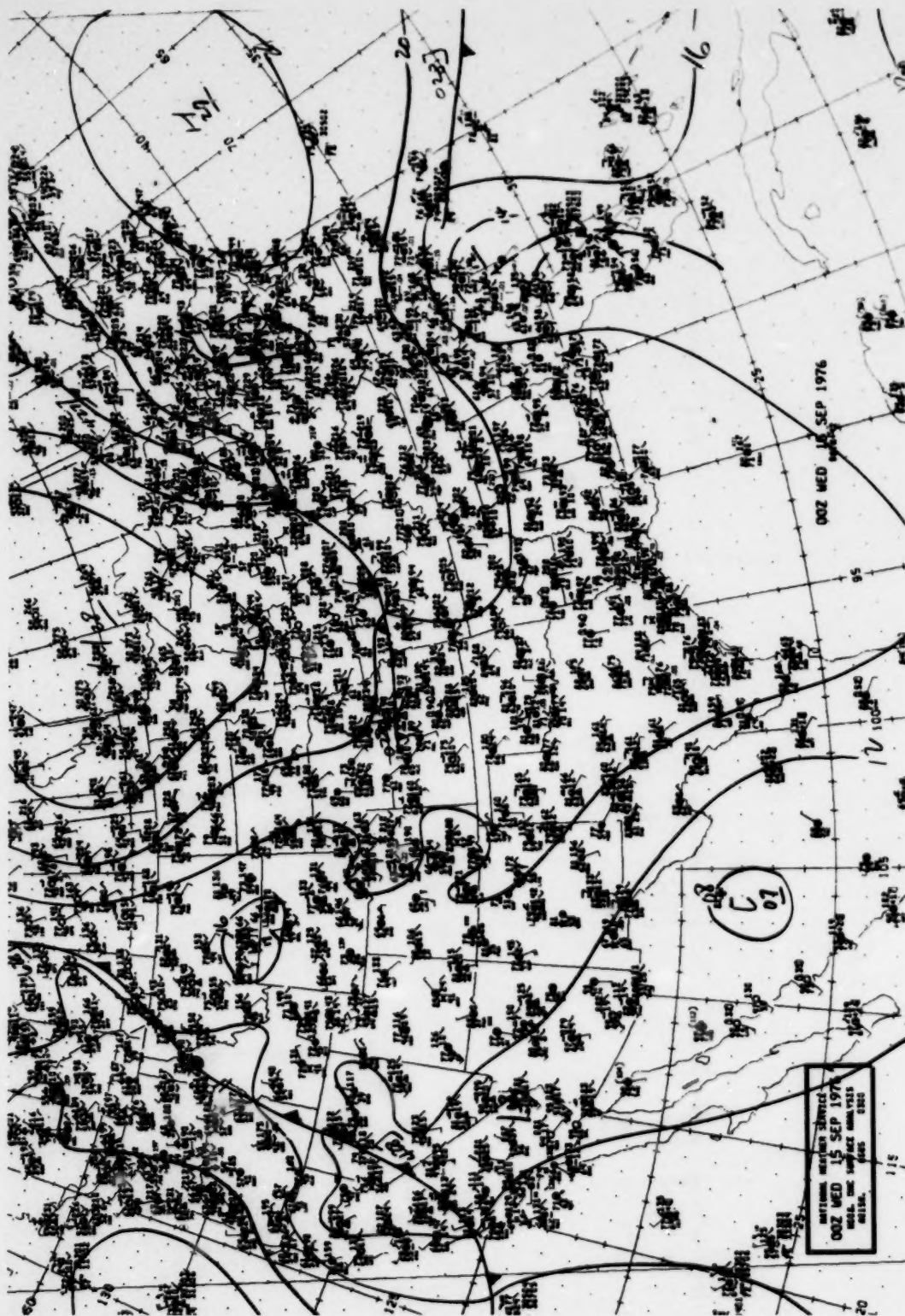


Base map type D(Geof)



Base map type F(GeOF)

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Base map type G(GeoF)



Base map type H(Geof)

